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A Nationwide Inventory of Emissions of Air Contaminants (1976)

Economic and Technical Review
Report EPS 3-AP-80-1

Air Pollution Control Directorate
January 1981

Canada

ENVIRONMENTAL PROTECTION SERVICE REPORT SERIES

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ERRATA

A NATIONWIDE INVENTORY OF EMISSIONS OF AIR CONTAMINANTS, 1976 (Report EPS 3-AP-80-1, January 1981)

Readers: After this report was printed, errors were detected in the calculation of emissions for "Industrial Fuel Combustion". This has necessitated changes to a number of tables as well as the abstract. These changes are indicated below.
We apologize for any inconvenience this may cause.

ABSTRACT (corresponding lines in résumé are in parenthesis):

line 6 (line 6)	-	5.4 should be replaced by 5.3
line 13 (line 15)	-	25.6% should be replaced by 25.7%
line 14 (line 17)	-	46.8% should be replaced by 47.8%
line 15 (line 17)	-	13.9% should be replaced by 12.1%
line 16 (line 19)	-	26.8% should be replaced by 27.2%
line 17 (line 19)	-	19.7% should be replaced by 18.4%

Table 1 - please use this new table in place of Table 1 in the text (page v).

Table 77 - please use this new table in place of Table 77 in the text (page 80). Also, these revised figures for Table 77 are to replace those under "Industrial Fuel Combustion" in Table 2 (page viii) and in Appendix Tables A-1 to A-11.

Table 88 - please use this new table in place of Table 88 in the text (page 90).

Table 89 - please use this new table in place of Table 89 in the text (page 91).

Copy A - these data are to replace those under Fuel Combustion/Stationary Sources - "Subtotal" - in Table 2 (page viii) and in Appendix Tables A-1 to A-11.

Copy B - these data are to replace those under "TOTAL" in Table 2 (page ix) and in Appendix Tables A-1 to A-11.



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TABLE 1 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, 1976 (Revised)

Category	Emissions (tonnes x 10 ³)							
	Particulate matter	% of total	Sulphur oxides*	% of total	Nitrogen oxides**	% of total	Hydrocarbons	% of total
Industrial processes	1 192	52.2	3 731	70.2	38	2.0	212	8.0
Fuel combustion/ stationary sources	301	13.2	1 499	28.2	652	35.1	142	5.3
Transportation	74	3.2	78	1.5	1 018	54.7	1 037	39.1
Solid waste incineration	34	1.5	3	0.1	5	0.3	26	1.0
Miscellaneous	682	29.9	-	-	147	7.9	1 234	46.6
TOTAL	2 284	100.0	5 311	100.0	1 860	100.0	2 651	100.0

* Expressed as SO₂** Expressed as NO₂2.1
32.9
100.0

TABLE 77 TOTAL EMISSIONS, INDUSTRIAL FUEL COMBUSTION, 1976 (Revised)

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	1 927	30 210	7 099	251	291
Prince Edward Island	19	292	83	2	10
Nova Scotia	2 142	33 673	7 778	276	297
New Brunswick	4 569	61 214	13 860	366	710
Quebec	22 476	255 744	63 613	1 947	3 633
Ontario	17 089	169 861	69 702	1 874	5 008
Manitoba	3 161	11 437	5 931	226	526
Saskatchewan	1 017	4 168	6 342	162	462
Alberta	2 399	15 037	144 933	1 704	1 126
British Columbia	4 983	58 249	23 491	821	1 327
Yukon, N.W.T.	75	1 154	446	14	61
TOTAL CANADA	59 857	641 039	343 278	7 643	13 451

* Expressed as SO₂** Expressed as NO₂

TABLE 88 TOTAL EMISSIONS, HEAVY FUEL OIL USE, 1976 (Revised)

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	2 004	27 264	5 810	68	350
Prince Edward Island	494	6 539	2 099	20	105
Nova Scotia	6 941	95 316	21 562	219	1 114
New Brunswick	4 678	78 286	18 718	193	1 006
Quebec	19 045	258 461	60 796	665	3 403
Ontario	8 302	141 356	37 619	442	2 250
Manitoba	503	6 630	1 963	21	110
Saskatchewan	44	586	174	1	9
Alberta	63	842	250	2	14
British Columbia	3 561	47 027	13 938	149	780
Yukon, N.W.T.	59	750	289	3	16
TOTAL CANADA	45 694	663 057	163 218	1 783	9 157

* Expressed as SO₂** Expressed as NO₂

TABLE 89 TOTAL EMISSIONS, LIGHT FUEL OIL USE, 1976 (Revised)

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	145	4 205	1 254	60	312
Prince Edward Island	44	1 065	365	18	96
Nova Scotia	348	9 359	3 033	122	648
New Brunswick	264	7 153	2 240	101	534
Quebec	1 851	54 155	15 703	764	4 014
Ontario	1 730	29 923	15 310	704	3 703
Manitoba	71	1 201	608	28	148
Saskatchewan	61	1 063	508	24	131
Alberta	38	670	324	16	83
British Columbia	280	4 829	2 298	114	597
Yukon, N.W.T.	28	563	300	13	69
TOTAL CANADA	4 860	114 186	41 943	1 964	10 335

* Expressed as SO₂** Expressed as NO₂

COPY A REVISED SUBTOTAL DATA FOR THE SECTION FUEL COMBUSTION/
STATIONARY SOURCES IN TABLE 2 (page viii) AND APPENDIX
TABLES A-I TO A-II

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro- carbons	Carbon monoxide
Newfoundland	3 768	43 385	11 145	3 865	6 993
Prince Edward Island	959	8 255	2 874	1 387	2 545
Nova Scotia	26 309	146 584	42 098	8 116	16 640
New Brunswick	13 868	128 620	26 535	6 910	12 792
Quebec	47 445	394 005	103 184	61 463	109 583
Ontario	37 392	604 316	192 256	33 988	65 930
Manitoba	9 589	21 479	16 694	6 020	11 086
Saskatchewan	40 984	32 862	38 387	8 075	15 312
Alberta	113 588	49 437	182 355	8 154	17 498
British Columbia	6 434	68 150	32 915	2 339	4 952
Yukon & N.W.T.	619	2 097	3 326	1 254	2 599
CANADA	300 955	1 499 190	651 769	141 571	265 930

* Expressed as SO₂

** Expressed as NO₂

COPY B REVISED DATA FOR TOTAL LINE OF TABLE 2 (page ix) AND APPENDIX
TABLES A-1 to A-11

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro- carbons	Carbon monoxide
Newfoundland	233 020	58 046	45 363	134 358	737 808
Prince Edward Island	2 978	8 714	8 177	8 921	50 160
Nova Scotia	72 242	166 101	77 438	79 918	408 242
New Brunswick	41 488	154 274	58 038	50 335	269 418
Quebec	557 416	1 103 099	324 276	488 969	2 443 923
Ontario	474 386	2 295 872	544 447	799 323	4 708 247
Manitoba	93 112	601 784	84 547	141 615	855 415
Saskatchewan	133 039	41 464	130 421	164 827	1 104 361
Alberta	184 458	511 400	325 038	215 217	1 286 064
British Columbia	253 163	368 046	195 227	243 918	1 647 319
Yukon & N.W.T.	238 624	2 862	67 060	323 891	1 887 699
CANADA	2 283 925	5 311 664	1 860 032	2 651 289	15 398 656

* Expressed as SO₂

** Expressed as NO₂

A NATIONWIDE INVENTORY OF EMISSIONS OF AIR CONTAMINANTS (1976)

Pollution Data Analysis Division
Air Pollution Programs Branch
Air Pollution Control Directorate

Report EPS-3-AP-80-1
January 1981

ABSTRACT

Atmospheric emissions of particulate matter, sulphur oxides, nitrogen oxides, hydrocarbons and carbon monoxide from various Canadian sources have been estimated for the year 1976.

Emission totals for the five major contaminants for five main source categories are presented in Table 1. During 1976, about 2.3 million tonnes of particulates, 5.4 million tonnes of sulphur oxides, 1.9 million tonnes of nitrogen oxides, 2.7 million tonnes of hydrocarbons and 15.4 million tonnes of carbon monoxide were released to the atmosphere. Industrial processes are the major source of particulate and sulphur oxide emissions, whereas nitrogen oxide, hydrocarbon and carbon monoxide emissions are predominantly from transportation sources.

A detailed breakdown of emissions of the five contaminants on a source-by-source basis is given in Table 2. Important single sources of particulate emissions are forest fires (25.6% of total) and iron ore mining and beneficiation (14.4% of total). Sulphur oxide emissions come primarily from primary copper and nickel smelting (46.8% of total) and industrial fuel combustion (13.9% of total). Nitrogen oxide emissions are mainly from gasoline-powered motor vehicles (26.8% of total) and industrial fuel combustion (19.7% of total). Gasoline-powered motor vehicles and forest fires are important sources of hydrocarbon emissions (33.1% and 31.3% of total). These two sources are also major contributors of carbon monoxide emissions (46.6% and 31.4% of total).

A novel feature of the inventory is the addition of five geographical maps of Canada, one for each contaminant, illustrating the emission densities of the contaminants on a 127 km by 127 km grid. These maps provide a snap-shot view of the magnitude and distribution of the emissions in Canada and appear on pages x to xiv.

Emissions of the five contaminants from each source surveyed have been further broken down on a provincial basis and are shown in Appendix A.

The five contaminants inventoried are the most significant from a quantitative point of view. Particulates are emitted in a wide range of compositions and sizes and their release is often subject to some form of control. Although emissions of sulphur oxides may be controlled, such is seldom the case for the other three contaminants (with the notable exception of pollution control devices on recent model motor vehicles).

Direct comparison between this report and a previous report entitled "A Nationwide Inventory of Emissions of Air Contaminants (1974)" is not advisable because of the variation in approaches in determining emissions from specific sectors. As more and better information is received, the accuracy of the emissions estimates improves. Thus, any comparison may mislead the reader in interpreting the actual change of air pollution levels in Canada between 1974 and 1976.

RÉSUMÉ

On a évalué les émissions atmosphériques de particules, d'oxydes de soufre, d'oxydes d'azote, d'hydrocarbures et de monoxyde de carbone provenant de diverses sources, au Canada, en 1976.

Au tableau 1, on trouve les valeurs des émissions totales de chacun des polluants considérés pour les cinq catégories majeures de sources. En 1976, environ 2,3 millions de tonnes de particules, 5,4 millions de tonnes d'oxydes de soufre, 1,9 millions de tonnes d'oxydes d'azote, 2,7 millions de tonnes d'hydrocarbures et 15,4 millions de tonnes de monoxyde de carbone ont été rejetées dans l'atmosphère. C'est surtout l'industrie qui a été la source des émissions de particules et d'oxydes de soufre, tandis que les moyens de transport ont surtout donné lieu aux émissions d'oxydes d'azote, d'hydrocarbures et de monoxyde de carbone.

La répartition détaillée des émissions de cinq polluants en fonction de la source est donnée au tableau 2. Les incendies de forêts ainsi que l'extraction et l'enrichissement du minerai de fer ont été des sources importantes d'émissions de particules (25,6 et 14,4 p. 100 du total respectivement). Les émissions d'oxydes de soufre ont été principalement attribuables aux fonderies de cuivre et de nickel de première fusion (46,8 p. 100 du total) et à l'utilisation des combustibles à des fins industrielles (13,9 p. 100 du total). Les émissions d'oxydes d'azote provenaient surtout des moteurs à essence (26,8 p. 100 du total) et de l'utilisation des combustibles à des fins industrielles (19,7 p. 100 du total). Les véhicules consommant de l'essence ainsi que les feux de forêt ont été d'importantes sources d'émissions d'hydrocarbures (respectivement 33,1 et 31,3 p. 100 du total), ainsi que de monoxyde de carbone (46,6 et 31,4 p. 100 du total).

Cet inventaire comprend une innovation en ce qui atrait la présentation de l'importance et de la répartition des émissions au Canada. Ainsi, cinq cartes géographiques ont été ajoutées, une pour chacun des polluants, présentant la densité des émissions sur une grille de 127 km par 127 km, à la grandeur du pays; ces cartes paraissent aux pages x à xiv.

Les émissions de chaque source étudiée ont, de plus, fait l'objet d'une compilation à l'échelle provinciale; les résultats en sont donnés dans l'annexe A.

Les cinq polluants inventoriés sont quantitativement les plus importants. Les particules rejetées varient grandement en grosseur et en composition et elles sont souvent recueillies par un dispositif antipollution quelconque. Les oxydes de soufre peuvent

également être interceptés de façon similaire. Toutefois, les trois autres polluants le sont rarement, sauf dans les voitures de modèle récent, munies d'un dispositif antipollution.

On évitera de comparer les données du présent rapport avec celles de "l'Inventaire national des rejets de polluants dans l'atmosphère (1974)" étant donné la nature différente des renseignements et les nouvelles méthodes de mesure utilisées. Une telle comparaison pourrait amener le lecteur à porter un jugement erroné sur l'évolution de la situation de la pollution atmosphérique entre 1974 et 1976.

TABLE 1 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, 1976

Category	Emissions (tonnes x 10 ³)									
	Particulate matter	% of total	Sulphur oxides*	% of total	Nitrogen oxides**	% of total	Hydrocarbons	% of total	Carbon monoxide	% of total
Industrial processes	1 192	52.0	3 731	68.8	38	2.0	212	8.0	926	6.0
Fuel combustion/ stationary sources	309	13.5	1 611	29.7	680	36.0	142	5.3	268	1.7
Transportation	74	3.2	78	1.4	1 018	53.9	1 037	39.1	8 820	57.3
Solid waste incineration	34	1.5	3	0.1	5	0.3	26	1.0	315	2.1
Miscellaneous	682	29.8	-	-	147	7.8	1 234	46.6	5 071	32.9
TOTAL	2 291	100.0	5 423	100.0	1 888	100.0	2 651	100.0	15 400	100.0

* Expressed as SO₂** Expressed as NO₂

TABLE 2 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, BY SOURCE, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES ¹					
Iron and steel production	48 536	2 241	-	-	212 634
Iron ore mining and beneficiation	329 714	175 829	-	-	41 030
Pyrrhotite roasting	3 435	63 980	-	-	-
Coal industry	62 146	-	-	-	-
Metallurgical coke manufacture	7 313	7 438	25	1 731	1 643
Primary aluminum production	16 843	27 864	5 105	831	89 284
Primary copper and nickel production	37 108	2 540 657	-	-	-
Primary lead and zinc production***	1 107	34 965	-	-	-
Copper and nickel refining	2 997	1 950	-	-	-
Ferroalloy manufacture	25 055	510	-	-	11 863
Abrasives manufacture	8 005	9 139	-	-	6 045
Ferrous foundries	10 346	-	-	-	6 162
Asbestos production	86 703	-	-	-	-
Cement manufacture	68 466	-	-	-	-
Asphalt production	37 304	-	-	-	-
Lime manufacturing	26 160	-	-	-	-
Gypsum processing	12 638	-	-	-	-
Nepheline syenite processing	415	-	-	-	-
Fluorspar processing	80	-	-	-	-
Silica processing	1 628	-	-	-	-
Stone processing	24 019	-	-	-	-
Sand and gravel processing	12 457	-	-	-	-
Mining and rock quarrying	123 541	-	-	-	-

¹ Includes only process emissions; emissions resulting from industrial fuel combustion are included under the category "Fuel Combustion/Stationary Sources".

TABLE 2 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, BY SOURCE, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	97 621	31 530	15 192	-	18 084
Sulphite pulping	956	66 471	-	-	-
Sulphuric acid production	-	8 066	-	-	-
Nitric acid production	-	-	7 488	-	-
Potash processing	20 207	-	-	-	-
Phosphate rock processing	4 146	-	-	-	-
Phosphate fertilizer manufacture	4 067	-	-	-	-
Elemental phosphorus production	8 557	1 736	-	-	-
Nitrate fertilizer manufacture	3 651	-	241	-	-
Grain handling	49 242	-	-	-	-
Grain milling	5 792	-	-	-	-
Clay products manufacture	13 491	-	-	-	-
Crude oil production	-	-	-	30 181	-
Petroleum refining	12 729	91 971	4 428	173 540	451 158
Natural gas processing	-	572 731	-	6 096	-
Tar sands operations	14 370	93 000	5 734	-	319
Glass manufacturing	1 278	-	-	-	-
Concrete batching	455	-	-	-	-
Magnesium production	251	-	-	-	-

TABLE 2 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, BY SOURCE, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Phosphoric acid production	67	-	-	-	-
Carbon black	10	1 358	-	61	87 812
Salt production	9 471	-	-	-	-
Subtotal	1 192 377	3 731 436	38 213	212 440	925 917
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	187 160	614 323	206 454	4 349	15 799
Residential fuel combustion	9 293	122 673	49 741	4 486	18 996
Industrial fuel combustion	68 180	753 311	371 280	7 943	15 027
Commercial fuel combustion	9 417	121 155	50 534	1 799	6 321
Fuelwood combustion	35 228	-	1 762	123 294	211 363
Subtotal	309 278	1 611 462	679 771	141 871	267 506
TRANSPORTATION					
Gasoline-powered motor vehicles	46 281	19 469	506 691	878 122	7 181 106
Railroads	8 350	22 007	94 234	23 222	33 795
Marine	1 048	6 669	4 277	23 462	66 022
Aircraft	438	600	5 382	7 170	37 811
Off-road use of gasoline	2 374	1 790	38 317	67 896	1 277 909
Diesel-powered engines	13 144	27 258	369 035	36 903	223 731
Tire wear	2 552	-	-	511	-
Subtotal	74 187	77 793	1 017 936	1 037 286	8 820 374

TABLE 2 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, BY SOURCE, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	7 965	1 567	1 789	896	21 410
Industrial and commercial incineration	1 284	772	841	258	926
Sewage sludge incineration	167	681	212	53	Neg.
Wigwam burners	24 759	225	2 252	24 759	292 605
Subtotal	34 175	3 245	5 094	25 966	314 941
MISCELLANEOUS					
Fertilizer application	6 255	-	-	-	-
Pesticide manufacturing and application	2 976	-	-	-	-
Gasoline and diesel marketing	-	-	-	211 620	-
Dry cleaning	-	-	-	28 306	-
Application of surface coatings	-	-	-	141 091	-
Forest fires	587 246	-	138 174	829 052	4 836 122
Structural fires	6 269	-	-	6 269	12 538
Slash burning	75 182	-	8 846	17 688	221 113
Cigarette smoking	4 303	-	-	-	1 721
Subtotal	682 231	-	147 020	1 234 026	5 071 494
TOTAL	2 292 248	5 423 936	1 888 034	2 651 589	15 400 232

* Expressed as SO₂

** Expressed as NO₂

*** Emissions from one plant are included under primary copper and nickel production to maintain confidentiality.

FIGURE 1

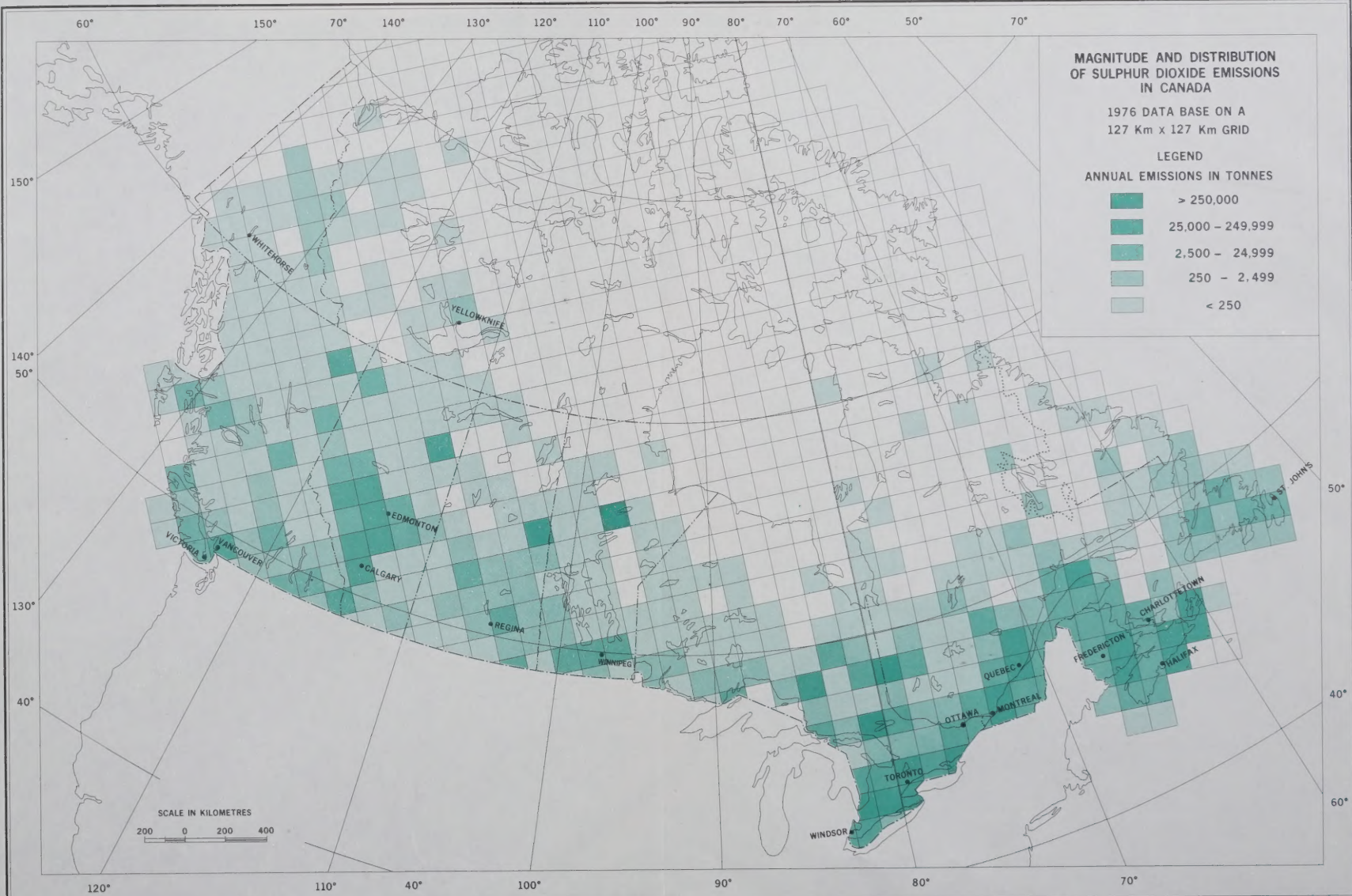
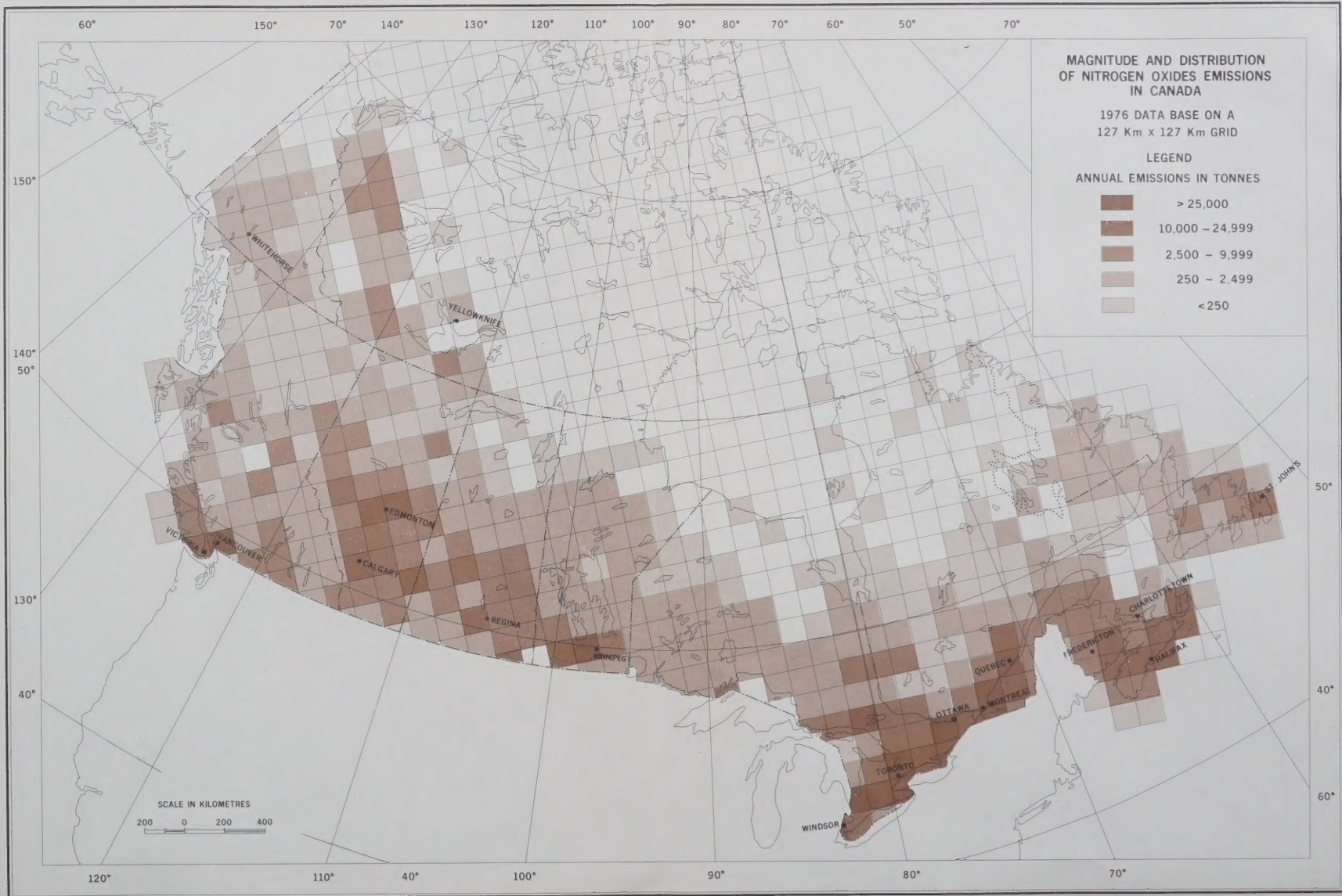
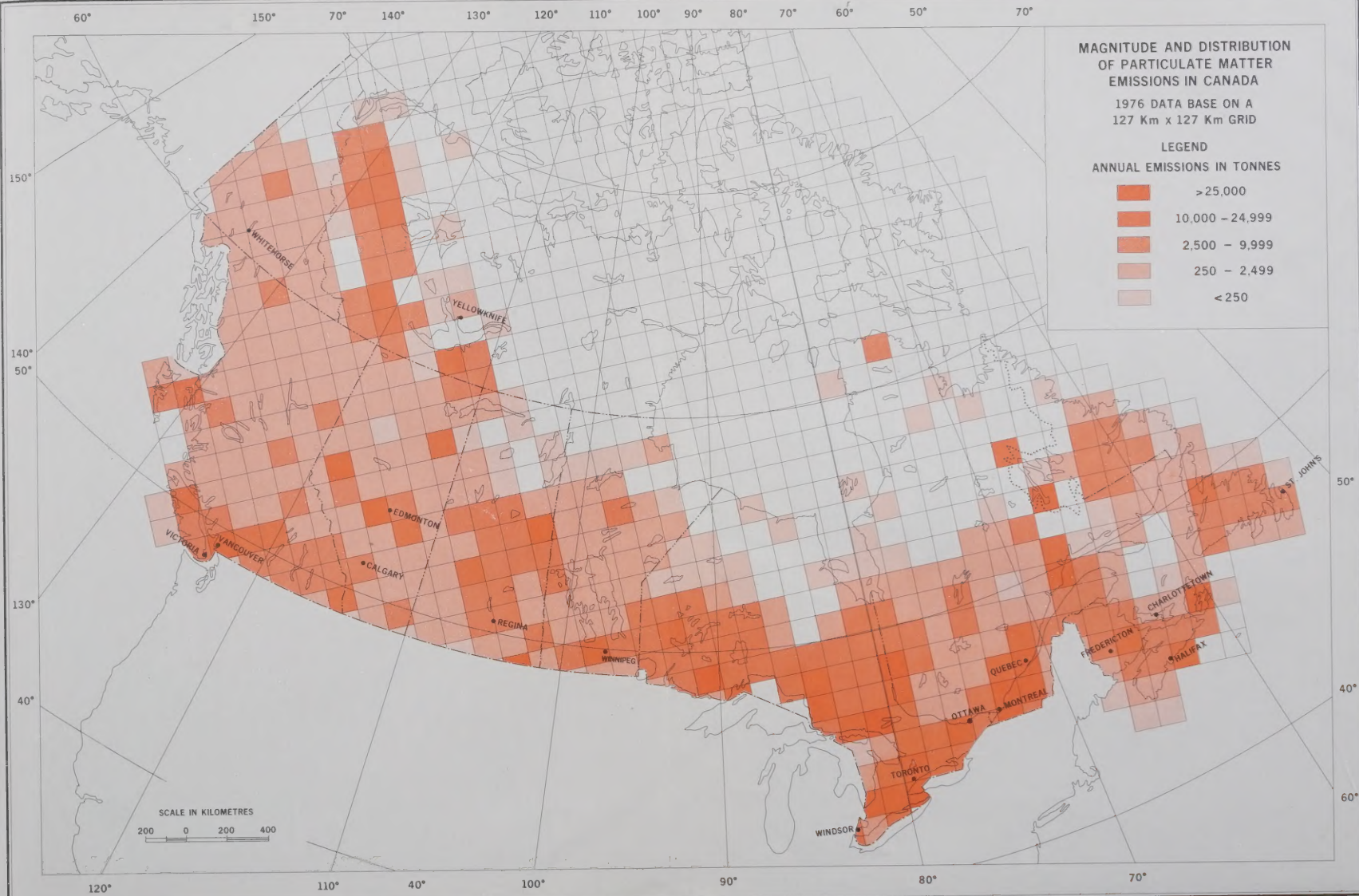


FIGURE 2





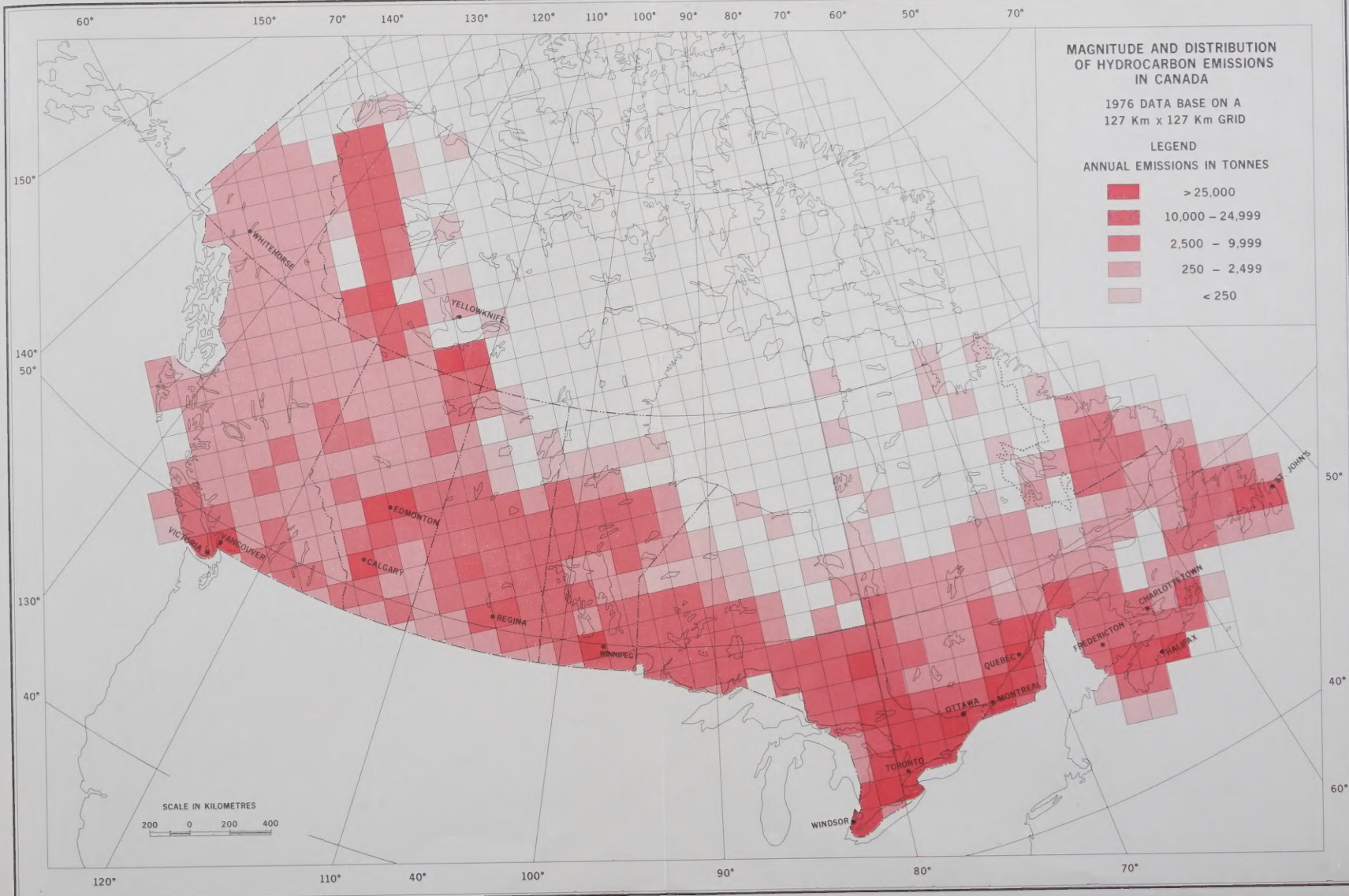


FIGURE 5

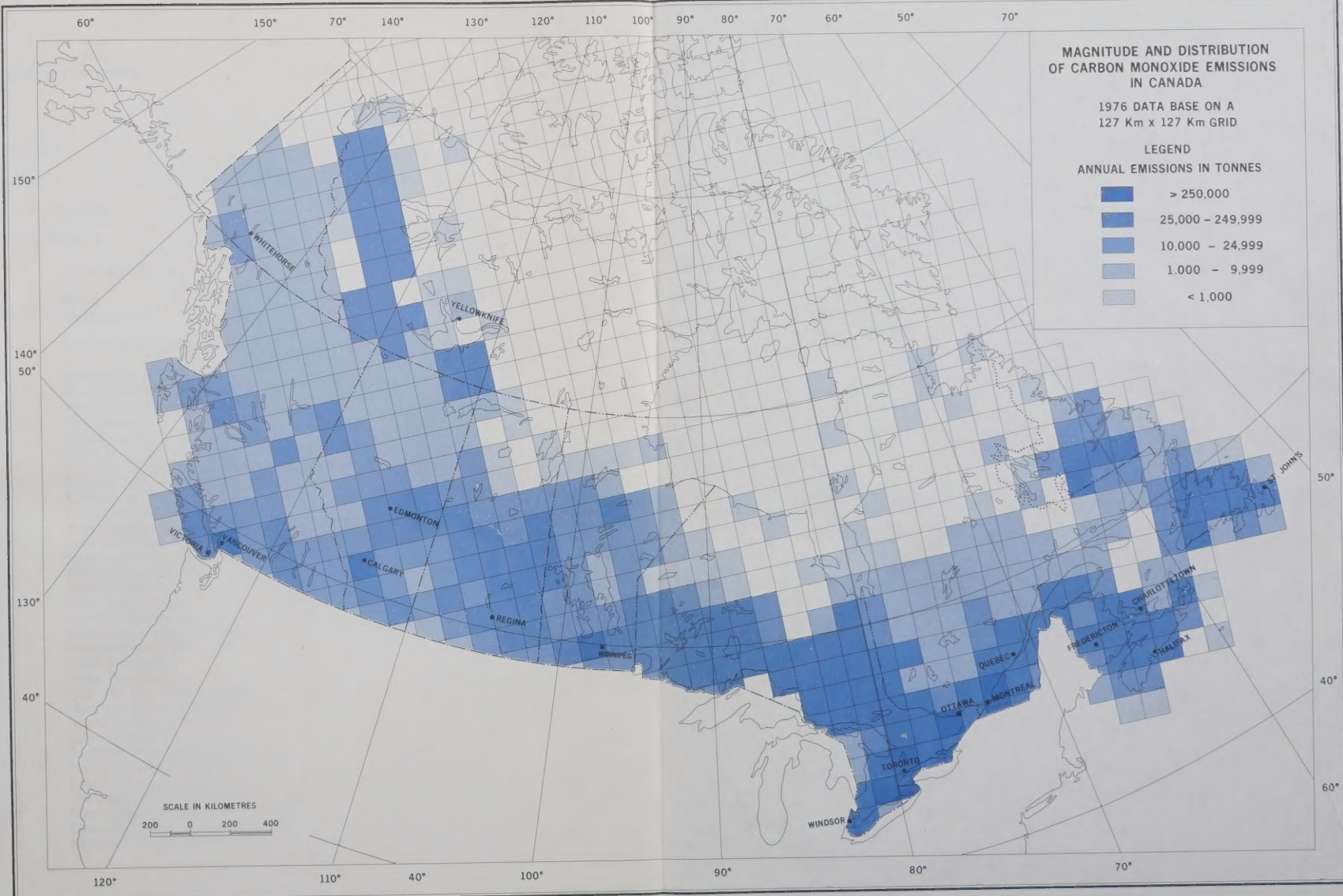


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1 INTRODUCTION

1.1 Scope

The purpose of this report is to identify and quantify sources of atmospheric emissions of the five primary air contaminants, in terms of source categories, for the year 1976. The contaminants considered are particulate matter, sulphur oxides, nitrogen oxides, hydrocarbons and carbon monoxide. Emissions are determined on a provincial basis in this report, however more detailed information on a census division basis is available through the Pollution Data Analysis Division.

A previous report entitled "A Nationwide Inventory of Emissions of Air Contaminants, 1974" (Report EPS 3-AP-78-2) was updated, using 1976 information to produce the report. Direct comparison between the two reports is not advisable because a number of new sources have been inventoried tending to increase emission totals. In addition, changes in emissions not attributable to trends have resulted from the use of better and more reliable information. The inventory is to be updated every two years and over a period of time it should reflect such factors as the impact of air pollution control legislation, changes in fuel use by consumers and trends in manufacturing activity.

1.2 Methodology

In assessing national air pollution on a national level, accurate data on the quantity and characteristics of emissions from all sources contributing to the problem are required. The large number of sources and the diversity of source types make impracticable the conducting of emission testing on a source-by-source basis at the point of release.

As much information as possible has been extracted from replies to various questionnaires sent to individual companies. Where such firsthand data were not available, it was necessary to adopt the 'emission factor' approach.

The emission factor is a statistical average of the rate at which a contaminant is released to the atmosphere as a result of some activity, such as combustion or industrial production, divided by the level of that activity. The emission factor, therefore, relates the quantity of each contaminant emitted to an appropriate 'base' quantity such as production or quantity of fuel burned. The source of most emission factors employed in this report is the "Compilation of Air Pollutant Emission Factors", published by the U.S. Environmental Protection Agency. Where available, emission

factors developed for Canadian conditions by the Air Pollution Control Directorate were used. Occasionally, only engineering estimates were available.

Information regarding production and fuel consumption by the various sources was usually obtained from either Statistics Canada or the Department of Energy, Mines and Resources. This was supplemented by data published by a number of industrial associations, and by information from other federal government departments.

Emissions have been estimated for 70 different source types. Each source type is dealt with separately in the following pages by a brief outline of the process, emission sources, controls and methodology used to estimate emissions.

The previous inventory contained a section on particulate emissions from unpaved roads which estimated the emissions from the Yukon and the Northwest Territories. This section has now been expanded to include the emissions from unpaved roads from the ten provinces. Given the magnitude of these emissions (and preliminary nature of the results), the sector has been excluded from the main summary tables so as not to dwarf the other emissions and can be found in Appendix B.

2 INDUSTRIAL EMISSIONS

2.1 Iron and Steel Industry

2.1.1 Process Description. Iron is commonly extracted from its ore in a blast furnace to which iron ore, coke, and limestone are fed and then reacted at high temperatures under a high-velocity stream of hot air. Molten iron is removed from the furnace and is either directly transported to a steel mill or cast into pigs. The flue dust and other iron ore fines from the process are converted into useful blast furnace charge via sintering operations. A special grade of pig iron called silvery pig iron, produced in an electric smelting furnace, was produced at one plant. Another plant produced metallized pellets by direct reduction techniques for application in further steelmaking operations. In steel production, pig iron and/or steel scrap are charged to either a basic oxygen, open hearth or electric arc furnace. Pellets can also be charged depending on the availability of scrap. All of the steelmaking processes produce molten steel.

After the molten steel has attained the desired chemical composition, it is tapped from the furnace into a ladle. Several plants pour the liquid steel into the top of open-bottomed moulds in continuous casting machines where it solidifies and is continuously withdrawn from the bottom of the moulds in long lengths of the desired shapes. Other ancillary operations include scarfing (removal of surface defects of the shaped steel, that must be further processed), cold and hot rolling and annealing (removal of self-contained stresses of steel products).

2.1.2 Emission Sources. Contaminants considered were particulate matter, sulphur oxides and carbon monoxide. The major contributors of particulate emissions are the various furnace operations. Sulphur oxide emissions result from the open hearth furnace and sintering operations, whereas carbon monoxide results from sintering operations, electric arc furnaces, and annealing operations.

2.1.3 Controls. Particulates discharged from pig iron and steelmaking furnace operations were controlled to various levels of efficiency. Venturi scrubbers and electrostatic precipitators were the most common control devices on blast furnaces (up to 99% efficiency); baghouses were used for electric arc furnaces; and basic oxygen furnaces were controlled by precipitators or venturi scrubbers. Various ancillary operations at some plants also had control devices. Sulphur oxides and carbon monoxide were assumed to be largely uncontrolled.

2.1.4 Emissions. Emissions from both primary and non-integrated steel plants were calculated based on industrial questionnaire replies and production data obtained from various sources (2, 7, 16). Emission factors were developed from the questionnaires for most processes, but where not available, were obtained from the U.S. Environmental Protection Agency (1), and appropriate control efficiencies were applied. Since these factors are site specific, no attempt has been made to list them.

Total emissions for iron and steel production are listed in Table 3.

TABLE 3 TOTAL EMISSIONS, IRON AND STEEL INDUSTRY, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia	17 785	458			
New Brunswick					
Quebec	8 784				175 527
Ontario	19 320	1 783			30 102
Manitoba	383				1 176
Saskatchewan	1 693				3 388
Alberta	307				1 682
British Columbia	264				759
Yukon, N.W.T.					
TOTAL CANADA	48 536	2 241			212 634

* Expressed as SO₂

** Expressed as NO₂

2.2 Iron Ore Mining and Beneficiation

2.2.1 Process Description. Iron ore is mined by either open-pit or underground methods and transported to a beneficiation plant. Some ores can be concentrated simply by crushing, screening, blending and washing; others require grinding and subsequent separation of the iron from other materials by flotation or magnetic separation. Concentrated ores are then agglomerated by sintering or pelletizing operations to produce suitably sized blast furnace feed. Pelletizing is usually done near the mine site, whereas sintering is performed at the steel mill. Only one plant in Canada sintered iron ore at the mine in 1976.

2.2.2 Emission Sources. Emissions resulted mainly from mining, crushing, grinding, pelletizing and sintering operations. Of total emissions, those from mining operations represented the largest portion and consisted mainly of fugitive dust and other particulate matter. Sulphur oxides and carbon monoxide were also released during sintering operations.

2.2.3 Controls. Emissions from mining operations were assumed to be uncontrolled. Crushing operations are controlled mainly by high efficiency cyclones, whereas grinding is an all-wet process, with negligible emissions. Overall efficiency for these two processes is assumed to be 70%. An overall 50% control efficiency was estimated for pelletizing plants, whereas the sintering operation was controlled by cyclones with 70% efficiency (3).

2.2.4 Emissions. Only the emissions from open-pit mining were considered because those from underground mining were assumed to be relatively minor. The quantity of ore mined by open-pit methods in 1976 was estimated from pertinent information (4,5). Only one sinter plant was included in this sector because all other sintering operations were carried out at integrated iron and steel plants. Emission factors from iron ore mining were considered to be the same as those for asbestos since they involved similar operations. Emission information for crushing and grinding and pelletizing operations was taken from questionnaire data, where available (7). All other emissions (except SO₂ sintering emissions) were calculated using emission factors from U.S. Environmental Protection Agency publications (1,6). Sulphur dioxide emissions from sinter plants were obtained from various sources (2, 122, 123).

Emission factors and total emissions for iron ore mining and beneficiation are presented in Tables 4 and 5 respectively.

TABLE 4 UNCONTROLLED EMISSION FACTORS, IRON ORE MINING AND BENEFICIATION

Operation	Emission factors (kg/tonne of ore)		
	Particulate matter	Sulphur oxides*	Carbon monoxide
Drilling	0.125		
Blasting	0.50		
Loading	0.50		
Hauling	0.25		
Unloading	0.50		
Crushing and grinding	1.0		
Pelletizing ^a	1.6		
Sintering ^b	21.0	c	22.0

* Expressed as SO₂

a Emission factor expressed as kg/tonne of pellets

b Emission factor expressed as kg/tonne of sinter

c Calculated from specific plant data

TABLE 5 TOTAL EMISSIONS, IRON ORE MINING AND BENEFICIATION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	142 268				
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	110 396				
Ontario	73 301	175 829			41 030
Manitoba					
Saskatchewan					
Alberta					
British Columbia	3 749				
Yukon, N.W.T.					
TOTAL CANADA	329 714	175 829			41 030

* Expressed as SO₂** Expressed as NO₂

2.3 Pyrrhotite Roasting

2.3.1 Process Description. Pyrrhotite concentrate is treated to convert the contained iron into a form suitable for use in the steel industry, by eliminating most of its sulphur content and extracting and recovering the major portion of non-ferrous metals.

Two plants were involved in the roasting of pyrrhotite in Canada in 1976. At one plant, the iron sulphide concentrate was oxidized to a low-sulphur calcine in the fluid bed roasters. The calcine was then processed through rotary kilns to reduce the non-ferrous metals selectively. These were in turn dissolved in an ammonia-ammonium carbonate solution. The solution was treated in a counter-current multi-stage leaching process for metal and reagent recovery and the leached iron oxide residue was pelletized and indicated. In the other plant, the sulphides were ground and individually separated by differential flotation. The iron sulphide was then roasted and the calcine transferred to a pond.

2.3.2 Emission Sources. The major emission sources from the pyrrhotite roasting process were the fluid-bed roasters and the reduction kilns. Particulates were also emitted during reagent recovery, pelletization and induration.

Particulate matter and sulphur oxides were the contaminants considered for these sources.

2.3.3 Controls. Particulate emissions from pyrrhotite roasting operations were generally well controlled. The facilities had sulphuric acid plants to control sulphur oxide emissions from the fluid-bed roasters. Before entering the acid plant, the gases were normally precleaned by cyclones and electrostatic precipitators. Cyclones and water scrubbers were used on the reduction kilns.

2.3.4 Emissions. The emissions were obtained from pertinent unpublished information (7, 8, 91) and are presented in Table 6.

2.4 Coal Industry

2.4.1 Process Description. This sector has been changed from a previous report to include coal mining and handling, transportation, as well as the cleaning aspect of the industry. The mining of coal is carried out in either underground or open-pit mines. Open-pit coal mining encompasses strip and auger mining of coal that lies near the earth's surface. Strip mining consists of removing the overburden, extracting the coal in a series of regular slices and then replacing the overburden. Auger mining involves removing

TABLE 6 TOTAL EMISSIONS, PYRRHOTITE ROASTING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario	3 185	58 590			
Manitoba					
Saskatchewan					
Alberta					
British Columbia	250	5 390			
Yukon, N.W.T.					
TOTAL CANADA	3 435	63 980			

* Expressed as SO₂** Expressed as NO₂

surface coal by boring holes into the coal bed using an auger. Underground mining involves the extraction of openings in the coal in two directions at right angles to one another. This method leaves behind coal remnants for natural support.

The concept of transporting coal by unit trains has been widely used. Once the coal has been deposited in port, barges are used in delivering the coal to individual customers or for export. A slurry pipeline provides an alternative to a rail-water system, but has not been used in Canada to date.

Cleaning removes most of the impurities from coal. The operation is carried out in coal preparation plants, where coal is screened, classified, washed and dried. Not all coal is cleaned in Canada (approximately 65%). This sector covers only the thermal drying of coal plants located only in western Canada.

2.4.2 Emission Sources. Particulate matter in the form of coal dust was the only contaminant considered for all operations. Fugitive dust is the major source in the

mining, handling and transportation of coal, whereas the thermal dryers were the major source of emissions from the coal cleaning operations.

2.4.3 Controls. An average control efficiency of 94% was used for the coal cleaning operations, usually using a combination of cyclone and scrubber for the drying operation. Coal in transport was sprayed with chemical binders. Water spray is used in mining operations when operating conditions are dry.

2.4.4 Emissions. The quantities of coal mined and handled on a provincial basis were obtained from the Department of Energy, Mines and Resources (9). Emission factors of 0.013 kg/tonne for mining and 0.006 kg/tonne for handling operations were derived by the Air Pollution Control Directorate (71). Emissions from coal transportation were obtained from the same source (71). Particulate emissions from British Columbia were calculated from various sources (9, 121), whereas Alberta emissions were determined using a controlled emission factor of 0.9 kg/tonne and plant production for 1976 (1, 9, 86).

Total emissions resulting from the coal industry are presented in Table 7.

2.5 Metallurgical Coke Manufacture

2.5.1 Process Description. Coke is formed in an oven by driving off the volatile constituents of coal such as tar, benzene and naphthalene. Most of the volatile constituents are condensed and recovered as by-products. The hot residue, known as coke, is water quenched and dried.

In Canada, coke is manufactured primarily by the by-product process. This involves heating coal in rectangular coking ovens grouped together in a series and alternately interspersed with heating flues. The overall assembly is called a coke battery.

2.5.2 Emission Sources. Emissions from coke making arose mainly from the following operations:

- Handling, crushing and blending of coals
- Charging of coal into incandescent ovens
- Underfiring the ovens with fuels containing sulphur
- Pushing the coke out of the ovens
- Quenching of hot coke
- Handling and screening of coke

2.5.3 Controls. In most plants, all operations were partly controlled to various degrees of efficiency.

TABLE 7 TOTAL EMISSIONS, COAL INDUSTRY, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia	128				
New Brunswick	231				
Quebec	1				
Ontario	451				
Manitoba	1 403				
Saskatchewan	1 639				
Alberta	3 042				
British Columbia	55 251				
Yukon, N.W.T.					
TOTAL CANADA	62 146				

* Expressed as SO₂** Expressed as NO₂

2.5.4 Emissions. Using the information on the quantities of coal used and coke produced for each coking plant (9), the emissions were calculated by emission factor techniques. The emission factors and control efficiencies were extracted from an Environment Canada report (13). Since coke oven gas is consumed also in an integrated steel plant, corrections were made to allow for coke oven gas used only in the coke plants (2).

Emission factors and total emissions from metallurgical coke manufacture are given in Tables 8 and 9 respectively.

2.6 Primary Aluminum Production

2.6.1 Process Description. The production of aluminum is a two-step process. First, bauxite ore is ground, purified and calcined to produce alumina; then the alumina is electrically smelted.

TABLE 8 UNCONTROLLED EMISSION FACTORS, METALLURGICAL COKE MANUFACTURE

Process	Emission factors (kg/tonne of coal charged)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Crushing and screening of coal and coke					
- coal	0.515				
- coke	0.045				
Charging	0.56	0.005-0.015	0.005	0.1	0.25
Pushing	0.515			0.1	0.05
Quenching	0.345				
Coking cycle	0.05		0.005	0.5	0.3
Underfiring	0.04-0.75	b			
Flaring	0.005	b			
Coke oven gas consumption	c	1.95-6.10 ^a			

* Expressed as SO₂

** Expressed as NO₂

a Total emission rate due to coke oven gas consumption throughout steel and coke complex

b Included in coke oven gas consumption

c Included in underfiring

TABLE 9 TOTAL EMISSIONS, METALLURGICAL COKE MANUFACTURE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia	669	1 982	2	83	109
New Brunswick					
Quebec	280	171	1	53	67
Ontario	5 700	4 604	20	1 462	1 335
Manitoba					
Saskatchewan	138	382	1	92	79
Alberta					
British Columbia	526	299	1	41	53
Yukon, N.W.T.					
TOTAL CANADA	7 313	7 438	25	1 731	1 643

* Expressed as SO₂** Expressed as NO₂

The major portion of the aluminum produced in Canada in 1976 was processed in either horizontal- or vertical-stud Soderberg reduction cells. Prebake-type cells are now used only to a limited extent.

2.6.2 Emission Sources. The major sources of emissions were the aluminum reduction cells, although a large amount of particulates can be generated during the calcining of aluminum hydroxide. Particulates were also emitted from bauxite grinding and materials handling. In addition, emissions of particulates, nitrogen oxides and sulphur oxides arose from the manufacture of carbon electrodes at three of the aluminum smelters.

2.6.3 Controls. Only one plant in Canada refined alumina in 1976. As the calcining operation relied on a high recovery of the emitted dust, the control equipment installed (multicyclones and baghouses) provided an overall particulate removal efficiency of approximately 95%. The bauxite grinding operation was controlled with a baghouse.

The electrolytic cells were normally covered and the exhaust fumes scrubbed before being discharged to the atmosphere. All the plants except one had scrubbers (either wet or dry) on the cell-hood stacks. Emissions not captured by the cell hoods were untreated and discharged through the roof ventilators.

Coke dust emissions from the making of carbon electrodes were controlled by multicyclones or scrubbers.

2.6.4 Emissions. Particulate emissions from alumina refining operations were calculated from questionnaire data (7, 10). Emissions from aluminum smelting and coke calcining were determined from an internal Air Pollution Control Directorate report (2) and other sources (7, 47, 91).

Emission factors and total emissions from primary aluminum production are presented in Tables 10 and 11 respectively.

TABLE 10 UNCONTROLLED EMISSION FACTORS, PRIMARY ALUMINUM PRODUCTION

Process	Emission factors (kg/tonne of product)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
ALUMINUM SMELTING ^a					
Overall emission factors	c	c	-	1.3	139.45
MAKING OF CARBON ELECTRODES ^a					
Coke Calcining ^b	2.6	19.9	21.5	-	-

* Expressed as SO₂

** Expressed as NO₂

a Controlled emission factors

b Emission factor expressed as kg/tonne coke processed

c Emissions obtained from actual plant data

TABLE 11 TOTAL EMISSIONS, PRIMARY ALUMINUM PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	14 483	20 579	3 299	539	57 948
Ontario					
Manitoba					
Saskatchewan					
Alberta					
British Columbia	2 360	7 285	1 806	292	31 336
Yukon, N.W.T.					
TOTAL CANADA	16 843	27 864	5 105	831	89 284

* Expressed as SO₂** Expressed as NO₂

2.7 Primary Copper and Nickel Production

2.7.1 Process Description. The first step in the production of copper and nickel involves the concentration of low-grade sulphide ores by magnetic separation and/or flotation methods. The primary metals are then recovered from the concentrate in four steps: roasting, smelting, converting and fire-refining.

In the roasting of concentrates, about half the sulphur is driven off as sulphur dioxide and some of the iron is oxidized. The resulting material, known as calcine, is fed into a smelting furnace along with a siliceous flux and melted to form an iron silicate slag, and solution of molten sulphides (matte). In converting, air is blown through the matte and additional sulphur is driven off the sulphide melt and the remaining iron is oxidized. The matte is reduced to the crude metals which are further refined.

The pyrometallurgical process described above was the most common method used in Canada in 1976. One plant also produced primary nickel by a hydrometallurgical process.

2.7.2 Emission Sources. The major sources of emissions were the roasters, smelting furnaces and converters. Minor emissions may also be released from ore handling and refining operations. The hydrometallurgical process is relatively free of emissions.

The contaminants considered for these sources were particulate matter and sulphur oxides.

2.7.3 Controls. Most of the plants used electrostatic precipitators to control particulate emissions from the gases from the roaster, smelting furnace and converter off-gases. In one case a baghouse was used for further cleaning of the combined reverberatory furnace and converter gas streams. Balloon flues, which serve as gravity collectors, and high-efficiency cyclones were also used at another plant.

One copper smelter operated an acid plant to recover SO_2 from combined fluid bed roaster and converter off-gas stream. Another plant recovers liquid SO_2 from a flash smelting furnace off-gas stream.

2.7.4 Emissions. Emissions were obtained from unpublished information as well as from questionnaire data and literature (2, 7, 11, 47, 12). Because of the differences in processes from one plant to the other, emission factors could not be compared.

Total emissions from primary copper and nickel production are listed in Table 12.

2.8 Primary Lead and Zinc Production

2.8.1 Process Description. Primary lead and zinc production consists of the extraction of metals from their ores.

Lead metal is produced by oxidizing the concentrate in a sinter plant where lead sulphides are converted to oxides of lead and sulphur dioxide. The oxidized solid material is reduced with coke in a blast furnace. The resulting molten lead bullion is further refined by either electrolysis or chemical precipitation.

All the primary zinc in Canada in 1976 was produced by the electrolytic process which involves the roasting of the concentrate to drive off the sulphur and obtain oxidized zinc. The reduction and recovery of zinc is achieved by leaching the calcine with sulphuric acid, followed by electrolysis where the zinc is plated onto cathodes. The zinc cathodes are then melted and cast into ingots.

TABLE 12 TOTAL EMISSIONS, PRIMARY COPPER AND NICKEL PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	11 446	601 363			
Ontario	12 926	1 367 768			
Manitoba	12 736	571 526			
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	37 108	2 540 657			

* Expressed as SO₂

** Expressed as NO₂

2.8.2 Emission Sources. The main emission sources in the primary lead and zinc industry were sinter plants, blast furnaces, roasters and electrolytic cells. Minor quantities of particulates were generated by ore crushing and materials-handling operations as well as from zinc melting furnaces.

Contaminants considered for these sources were particulate matter and sulphur oxides.

2.8.3 Controls. All the primary zinc producers, except one, had acid plants to control emissions of sulphur oxides from the roasters. Before entering the acid plant, the gases were cleaned by waste heat boilers and cyclones, followed by electrostatic precipitators and scrubbers to remove particulates. Emissions from zinc melting furnaces were normally controlled by impingers or by cyclones and baghouses.

The Canadian lead producers used scrubbers or an acid plant to control the sintering operations, and baghouses to control the blast furnace exhaust gases.

2.8.4 Emissions. Production data were taken from the literature (13, 14). Controlled emission factors were determined internally through questionnaire submissions and varied from one plant to another (7).

Total emissions for primary lead and zinc production are given in Table 13.

TABLE 13 TOTAL EMISSIONS, PRIMARY LEAD AND ZINC PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick	233	11 979			
Quebec	188	4 398			
Ontario	97	2 052			
Manitoba ^a					
Saskatchewan					
Alberta					
British Columbia	589	16 536			
Yukon, N.W.T.					
TOTAL CANADA	1 107	34 965			

* Expressed as SO₂

** Expressed as NO₂

a Emissions from this province are included under primary copper and nickel sector

2.9 Copper and Nickel Refining

2.9.1 Process Description. The product at nickel and copper smelters is fire-refined metal at a purity of about 99.5 percent. For most applications, further purification of the metals is required; the fire-refined metals are cast into 'Anodes' and shipped to refineries for electrolytic refining. Impurities are separated from the metals by electrolysis in large tanks. The metallic impurities form a sludge which is treated for precious metal recovery, generally using pyro-metallurgical processes. In the electrolysis, the nickel or

copper is transferred onto the cathode which is remelted and made into marketable shapes.

2.9.2 Emission Sources. The major sources of emissions are the anode and remelting furnaces. Anode furnaces are used at refineries for remelting defective anodes and other scrap material. The electrolysis process is relatively free of emissions. Process emissions consist of particulates and sulphur oxides.

2.9.3 Controls. Electrostatic precipitators are used primarily to control the particulate emissions from furnaces. Baghouses are commonly used in other areas of controlling particulate emissions.

2.9.4 Emissions. Emissions from two major refineries were determined based on questionnaire data (7) and literature (2, 11). Using this information, emission factors were developed and applied to the other refineries.

Total emissions from copper and nickel refining are listed in Table 14.

TABLE 14 TOTAL EMISSIONS, COPPER AND NICKEL REFINING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	45				
Ontario	2 928	1 950			
Manitoba	24				
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	2 997	1 950			

* Expressed as SO₂

** Expressed as NO₂

2.10 Ferroalloy Manufacture

2.10.1 Process Description. Various kinds and grades of ferroalloys are produced in Canada. The main products are ferrosilicon, ferromanganese, silicomanganese and ferrochromium. The major portion of the ferroalloys produced in Canada in 1976 was processed in open-top electric furnaces. An aluminothermic furnace was used at one plant for the production of special alloys such as ferromolybdenum, ferrovanadium and ferrocolumbium.

The typical electric furnace used in the manufacture of ferroalloys is the submerged-arc type. Raw ore, coke and slagging materials are charged to the furnace in appropriate quantities. The intense heat zone around the carbon electrodes enables carbon reduction of the metallic oxides. The various impurities are trapped in the slag and molten ferroalloy is tapped from the bottom of the furnace and cast.

2.10.2 Emission Sources. The electric-smelting-furnace production method is a major source of air pollution. Large quantities of carbon monoxide are generated as a result of the carbon reduction of metallic oxides. The escaping gas also carries a substantial amount of particulates of submicron size. Particulate matter is emitted from raw-materials handling, crushing, grinding and sizing operations.

2.10.3 Controls. There were no controls on most of the furnace operations. It was estimated that the aluminothermic process was controlled to about 70% efficiency. Ancillary operations were usually well controlled. Baghouses were used in most situations with some use of cyclones.

2.10.4 Emissions. Production data, obtained from questionnaires (2), were used along with internally developed emission factors and unpublished information (47). Sulphur dioxide emissions were determined from the same source, whereas carbon monoxide emission factors were derived from pertinent literature (17, 18).

There were also some industries which produced ferrosilicon and ferrophosphorus as by-products of their main process. Usually, however, these by-products were transported to waste dumps along with slag. These operations have not been included here. However, emissions from the production of calcium carbide have been included.

Emission factors and total emissions for ferroalloy manufacture are presented in Tables 15 and 16 respectively.

TABLE 15 UNCONTROLLED EMISSION FACTORS, FERROALLOY MANUFACTURE

Product or Operation	Emission factors (kg/tonne of product)	
	Particulate matter*	Carbon monoxide ^a
15% ferrosilicon		unknown
50% ferrosilicon		66.5
65%-90% ferrosilicon		85.5
Silicon metal		200
Silicomanganese		unknown
High-carbon ferromanganese		50.0
Low-carbon ferromanganese		50.5
Medium-carbon ferromanganese		50.5

a Emission factors based on the assumption that 10% of the CO produced in the furnace escapes to the atmosphere.

* Emission factors developed on a plant-by-plant basis.

TABLE 16 TOTAL EMISSIONS, FERROALLOY MANUFACTURE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	25 000	510			11 863
Ontario	55				
Manitoba					
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	25 055	510			11 863

* Expressed as SO₂

** Expressed as NO₂

2.11 Abrasives Manufacture

2.11.1 Process Description. Two types of synthetic abrasives are manufactured in Canada; aluminum oxide and silicon carbide.

The production of aluminum oxide involves the smelting of bauxite ore in an electric furnace along with iron borings and coke. The by-product of this process is ferrosilicon.

The production of silicon carbide involves the smelting of silica sand with petroleum coke in an electric-resistance furnace. The final product is then cooled and crushed.

2.11.2 Emission Sources. Substantial amounts of dust and fumes are created during smelting operations. Particulate emissions also occur from the drying of petroleum coke and from product sizing.

Large amounts of particulate are released from both synthetic abrasives manufacturing processes. Unreacted carbon monoxide is evolved in the silicon carbide process, and, to a lesser degree, in the production of aluminum oxide. Part of the sulphur contained in the petroleum coke used in silicon carbide production is released as sulphur oxides. One company uses elemental sulphur to increase the purity of its aluminum oxide.

2.11.3 Controls. The melting operation in aluminum oxide production was controlled in a limited number of installations by a baghouse; emissions from resistance furnaces in silicon carbide processing were uncontrolled. The level of control for the industry as a whole was assumed to be minimal.

2.11.4 Emissions. Plant production was obtained from a Statistics Canada publication (60). Emission factors for the industry were obtained from the Air Pollution Control Directorate and from unpublished information (2, 47). Emissions from by-products have not been included as they are already considered in the overall plant emissions.

Emission factors and total emissions for abrasives manufacture are presented in Tables 17 and 18 respectively.

2.12 Ferrous Foundries

2.12.1 Process Description. Iron and steel castings are produced in one of four furnaces: cupola, reverberatory, electric induction or electric arc. The cupola was the furnace most widely encountered in Canada in 1976, although the other types were also used to a limited extent.

TABLE 17 UNCONTROLLED EMISSION FACTORS, ABRASIVES MANUFACTURE

Process	Emission factors (kg/tonne of product)				Carbon monoxide
	Particulate Matter		Sulphur oxides*		
	Fused Aluminum	Silicon Carbide	Fused Aluminum	Silicon Carbide	
Abrasives manufacture					
Ontario	25.1 **	24.2	120.6	22.1	25.0
Quebec	91.9	24.6	2.8	22.1	25.0

* Expressed as SO₂

** Average controlled emission factor

TABLE 18 TOTAL EMISSIONS, ABRASIVES MANUFACTURE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	3 498	5 398			1 509
Ontario	4 507	3 741			4 536
Manitoba					
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	8 005	9 139			6 045

* Expressed as SO₂** Expressed as NO₂

The furnace charge consists of metallics, flux materials and, in the case of cupola melting, coke for fuel. Molten metal is tapped into a temporary holding unit or into a ladle for pouring into moulds. When cooled, the mould is transferred to a shake-out area where the sand and castings are separated by manual or mechanical means.

2.12.2 Emission Sources. The major emission source is the cupola furnace, with the electric arc, induction and reverberatory furnaces emitting smaller amounts. Emissions consist of metallic oxides, fumes, dust and gases. A large amount of particulate matter is also generated by non-melting operations such as shake-out, shot-blasting and sand conditioning.

Contaminants considered for these sources were particulate matter and carbon monoxide.

2.12.3 Controls. A variety of air pollution control equipment was used on melting operations. Scrubbers and wet caps were commonly installed on cupolas, although cyclones and sometimes baghouses were also used. Collector units used on electric arc furnaces were baghouses and scrubbers. In addition to the dust collection equipment systems, a variety of hoods, ventilating and exhaust systems were employed to capture or exhaust foundry emissions. Particulate matter control on a provincial basis was estimated to vary between 10% and 65%. Carbon monoxide emissions were assumed to be controlled with afterburners on cupola furnaces.

2.12.4 Emissions. Production figures for the ferrous foundry industry were obtained from various sources (75, 76). Production from steel foundries also included production from electric furnaces at steel plants and were thus subtracted from the total. Emission factors, available on a plant-by-plant basis, were averaged in order to obtain a national figure.

Emission factors and total emissions for ferrous foundries are presented in Tables 19 and 20 respectively.

2.13 Asbestos Production

2.13.1 Process Description. The production of asbestos involves two major operations, mining and milling.

Mining consists of extracting the fibre-bearing ore from the mines and transporting it to the mill. The milling operation involves the separation of the asbestos fibre (e.g. chrysotile) from coexisting rock by coarse crushing, drying and recrushing in stages. Each step is followed by screening and air suction, to free the fibres from rock

TABLE 19 AVERAGE EMISSION FACTORS, FERROUS FOUNDRIES

Type of Furnace	Emission factors* (kg/tonne of melt)	
	Particulate matter	Carbon monoxide
Cupola	2.85	4.5
Reverberatory	1.0 ^a	
Induction	0.75 ^a	
Electric Arc	2.10	
Non-Melting Operations	2.66	

* These factors have been determined from individual plant data and have been averaged by dividing the total emissions by the total of hot metal produced.

a Uncontrolled emission factor.

TABLE 20 TOTAL EMISSIONS, FERROUS FOUNDRIES, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	4				1
Prince Edward Island	9				2
Nova Scotia	149				26
New Brunswick	446				118
Quebec	3 648				906
Ontario	4 290				4 598
Manitoba	659				78
Saskatchewan	28				5
Alberta	623				258
British Columbia	490				170
Yukon, N.W.T.					
TOTAL CANADA	10 346				6 162

* Expressed as SO₂

** Expressed as NO₂

and dust. The asbestos fibres are cleaned, graded and bagged for shipment and the waste is conveyed to tailings dumps.

2.13.2 Emission Sources. Each of the processes associated with asbestos mining and milling is a potential emission source. Significant sources of particulate matter are tailings disposal and mining operations. Minor quantities of particulates are generated by crushing and drying of asbestos ore, as well as milling and shipping operations.

Particulate emissions considered for these sources included both rock dust and asbestos fibre.

2.13.3 Controls. Most of the asbestos milling facilities had emission control equipment. Cyclones and baghouses operating at estimated control efficiencies of 70% and 99.8% respectively were commonly used.

2.13.4 Emissions. Particulate emissions from the Canadian asbestos industry were calculated using production data (97) and emission factors developed from an Environment Canada report (96). These emission factors were based on particulate emission reduction for various processes, relative to the 1974 inventory (3).

Emission factors and total emissions for asbestos production are listed in Tables 21 and 22 respectively.

2.14 Cement Manufacture

2.14.1 Process Description. Cement is produced by quarrying and crushing limestone, and shale or clay. The raw materials are proportioned, ground and blended using either the wet or dry process. Slurry and dry raw materials are burned in a kiln to form clinker, which is then blended with a small amount of gypsum, ground into fine powder, and stored.

2.14.2 Emission Sources. The main pollution problem associated with cement manufacturing is the emission of particulates resulting from the following operations.

- Quarrying and crushing
- Preparation of raw materials
- Kiln operations
- Clinker cooling
- Finish grinding
- Packaging

Of the above sources, emissions from kiln operations represent the largest portion.

TABLE 21 CONTROLLED EMISSION FACTORS, ASBESTOS PRODUCTION

Process	Emission factors (kg/tonne of ore mined)	
	Particulate Matter	
	Quebec	Rest of Canada
Crushing	0.03	0.05
Drying	0.12	0.13
Dry-rock storage	0.03	0.04
Milling	0.83	0.89
Tailings	49.55	80.64

TABLE 22 TOTAL EMISSIONS, ASBESTOS PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	7 277				
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	63 014				
Ontario	2 198				
Manitoba					
Saskatchewan					
Alberta					
British Columbia	5 759				
Yukon, N.W.T.	8 455				
TOTAL CANADA	86 703				

* Expressed as SO₂** Expressed as NO₂

2.14.3 Controls. All the cement plants in Canada had some type of emission control system operating at various degrees of efficiency. The most common were electrostatic precipitators on kiln exhaust gases and high efficiency baghouses on finish grinding operations.

2.14.4 Emissions. To calculate emissions, Canadian cement production statistics and controlled particulate emission factors (developed from industrial questionnaire data) were used (19,2).

Estimated total particulate emissions attributable to cement manufacture are presented in Table 23.

TABLE 23 TOTAL EMISSIONS, CEMENT MANUFACTURE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	834				
Prince Edward Island					
Nova Scotia	2 509				
New Brunswick	356				
Quebec	56 423				
Ontario	1 598				
Manitoba	2 008				
Saskatchewan	1 133				
Alberta	2 814				
British Columbia	791				
Yukon, N.W.T.					
TOTAL CANADA	68 466				

* Expressed as SO_2

** Expressed as NO_2

2.15 Asphalt Production

2.15.1 Process Description. The first step in the production of hot-mix asphalt is the conveying of proportioned quantities of cold aggregates, such as sand, slag or fragments of stone and gravel, to a dryer. Dry aggregates are then screened, classified and mixed with hot asphalt. The final mixing process can be either of the batch or continuous type.

2.15.2 Emission Sources. The asphalt rotary dryer is the major source of emissions. Uncontrolled emissions from this source amount to approximately 5% of the total weight throughput. Other sources of particulate emissions include hot aggregate elevators, screens, storage bins, weigh hoppers, mixers, and transfer points.

2.15.3 Controls. Most of the asphalt plants in Canada had some type of air pollution control equipment, mainly wet scrubbers and baghouses, with some multicyclones. The degree of control was estimated to vary between 70% and 99%.

2.15.4 Emissions. To calculate emissions, Canadian asphalt sales, assumed equivalent to production, were used in combination with Air Pollution Control Directorate emission factors (46, 52). For Alberta, the emission factor was developed through source testing by Alberta Environment (109). Asphalt mix was assumed to contain 7% asphalt and 93% aggregate by weight (22). Asphalt weighed 4.76 kg per imperial gallon (48).

Estimated total particulate emissions attributable to asphalt production are presented in Table 24.

2.16 Lime Manufacture

2.16.1 Process Description. The production of lime involves the crushing and handling of carbonate rocks more commonly known as limestone. The burning of lime consists essentially of the calcination of limestone at a sufficiently high temperature to decompose the calcium carbonate and drive off the gaseous carbon dioxide. Calcination is accomplished in kilns of various types but those of vertical and rotary design are mainly used in Canada.

2.16.2 Emission Sources. The major sources of emissions were the crushing, handling and lime kiln operations. Particulate matter was the only contaminant considered for these sources.

2.16.3 Controls. The degree of control for each province was estimated by the Air Pollution Control Directorate. It was assumed that emissions from crushing operations were controlled at efficiencies varying from 50% to 85%, whereas those from rotary kilns

TABLE 24 TOTAL EMISSIONS, ASPHALT PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	985				
Prince Edward Island	1 199				
Nova Scotia	1 913				
New Brunswick	2 883				
Quebec	12 281				
Ontario	6 487				
Manitoba	2 573				
Saskatchewan	3 590				
Alberta	1 250				
British Columbia	4 115				
Yukon, N.W.T.	28				
TOTAL CANADA	37 304				

* Expressed as SO₂

** Expressed as NO₂

were controlled from 70% to 90%. Emissions from vertical kilns were considered to be uncontrolled.

2.16.4 Emissions. To calculate emissions, Canadian lime production statistics and U.S. Environmental Protection Agency emissions factors were used (1, 21). This was supplemented by data on the type of kilns and capacities for each Canadian plant (23).

Emission factors and total emissions for lime manufacture are listed in Tables 25 and 26 respectively.

2.17 Gypsum Processing

2.17.1 Process Description. The processing of gypsum, a naturally occurring hydrated calcium sulphate mineral, involves the drying, grinding and handling of aggregates in preparation for calcining.

Calcination of finely ground gypsum takes place in a large heated calciner, where gypsum loses its water of hydration and becomes plaster of paris.

TABLE 25 UNCONTROLLED EMISSION FACTORS, LIME MANUFACTURE

Process	Emission factors (kg/tonne of lime)
	Particulate Matter
CRUSHING	
Primary	15.5
Secondary	1.0
CALCINING	
Vertical kiln	4.0
Rotary kiln	100.0
Vibratory kiln	100.0
Calcimatic kiln	100.0

TABLE 26 TOTAL EMISSIONS, LIME MANUFACTURE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick	1 568				
Quebec	11 164				
Ontario	9 316				
Manitoba	1 624				
Saskatchewan					
Alberta	1 810				
British Columbia	678				
Yukon, N.W.T.					
TOTAL CANADA	26 160				

* Expressed as SO₂** Expressed as NO₂

2.17.2 Emission Sources. The major source of emission was the calciner. Other sources were operations involved in the grinding and drying of raw materials.

Particulate matter was the only contaminant considered for these sources.

2.17.3 Controls. Specific information on the control equipment actually installed in 1976 was not available. Therefore, an overall control efficiency of 90% was assumed. Baghouses and electrostatic precipitators are the most widely used control equipment.

2.17.4 Emissions. Emissions of particulates by the gypsum processing industry were calculated using U.S. Environmental Protection Agency emission factors (1) and related information on production data (24). It was assumed that processing of the gypsum was not done at the mine site, as was done in previous calculations (3).

Emission factors and total emissions for gypsum processing are presented in Tables 27 and 28 respectively.

TABLE 27 UNCONTROLLED EMISSION FACTORS, GYPSUM PROCESSING

Process	Emission factors (kg/tonne of throughput)
	Particulate Matter
Raw materials drying	20.0
Primary grinding	0.5
Calcining	45.0
Conveying	0.35
Total	65.85

2.18 Nepheline Syenite Processing

2.18.1 Process Description. Nepheline syenite processing involves the crushing and blending of quarry material from various parts of the pit to ensure an acceptable mill feed.

Ontario was the only Canadian province involved in nepheline syenite processing in 1976. Two mills were in operation processing rock from three quarries.

2.18.2 Emission Sources. Dust emissions originate from crushing and screening, milling, handling, and from storage piles.

TABLE 28 TOTAL EMISSIONS, GYPSUM PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	230				
Prince Edward Island					
Nova Scotia	152				
New Brunswick	276				
Quebec	3 160				
Ontario	4 390				
Manitoba	546				
Saskatchewan	330				
Alberta	988				
British Columbia	2 566				
Yukon, N.W.T.					
TOTAL CANADA	12 638				

* Expressed as SO₂

** Expressed as NO₂

2.18.3 Controls. An industry-average control efficiency of 95% was assumed on all sources except conveying and handling operations, which were assumed to be uncontrolled.

2.18.4 Emissions. Data on the production of nepheline syenite were given in the literature (25). Emission factors were obtained from a U.S. Environmental Protection Agency publication (1). Storage pile losses were estimated using a form of the Thornthwaite Moisture Index (7).

Emission factors and total emissions for nepheline syenite processing are presented in Tables 29 and 30 respectively.

2.19 Fluorspar Processing

2.19.1 Process Description. This process involves the primary and secondary crushing, screening and handling of fluorspar aggregates.

TABLE 29 UNCONTROLLED EMISSION FACTORS, NEPHELINE SYENITE PROCESSING

Operation	Emission factors (kg/tonne)
	Particulate Matter
CRUSHING OPERATIONS	
Primary crushing	0.25
Secondary crushing and screening	0.75
Recrushing and screening	2.5
Fines mills	3.0
MISCELLANEOUS OPERATIONS	
Screening, handling and conveying	1.0
Storage pile losses	0.14

TABLE 30 TOTAL EMISSIONS, NEPHELINE SYENITE PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario	415				
Manitoba					
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	415				

* Expressed as SO₂

** Expressed as NO₂

All fluorspar produced in Canada in 1976 was mined in Newfoundland by one company.

2.19.2 Emission Sources. Dust emissions occurred from all the above operations, as well as from storage piles.

2.19.3 Controls. Crushing and screening operations were controlled to 95%, whereas conveying and handling operations were uncontrolled.

2.19.4 Emissions. Because emission factors for fluorspar processing were not available, those for stone processing were assumed to be applicable (1). Production data were obtained from the literature (70). Storage pile losses were estimated using a form of the Thorntwaite Moisture Index (7).

Emission factors and total emissions for fluorspar processing are given in Tables 31 and 32 respectively.

TABLE 31 UNCONTROLLED EMISSION FACTORS, FLUORSPAR PROCESSING

Operation	Emission factors (kg/tonne of product)
	Particulate Matter
Primary crushing	0.25
Secondary crushing and screening	0.75
Screening, conveying and handling	1.0
Storage pile losses	0.05

2.20 Silica Processing

2.20.1 Process Description. Silica processing involves the primary and secondary crushing, screening, milling and handling of aggregates.

2.20.2 Emission Sources. Dust emissions originate mainly from the crushing and screening operations, from milling and from storage piles.

TABLE 32 TOTAL EMISSIONS, FLUORSPAR PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	80				
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario					
Manitoba					
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	80				

* Expressed as SO₂

** Expressed as NO₂

2.20.3 Controls. Control efficiencies of 95% were assumed for the crushing and screening operations, and 70% for conveying and handling since dust pick-up points do not cover the whole operation. Baghouses are the control equipment utilized.

2.20.4 Emissions. Particulate emissions were estimated using U.S. Environmental Protection Agency emission factors for stone processing as well as published production data (1, 20). Since some provincial production data were not available, values were obtained by proration based on dollar values. Storage pile losses were estimated using a form of the Thornthwaite Moisture Index (7).

Emission factors and total emissions for the silica processing industry are presented in Tables 33 and 34 respectively.

2.21 Stone Processing

2.21.1 Process Description. This process involves the primary and secondary crushing, screening, milling and handling of stone aggregates.

TABLE 33 UNCONTROLLED EMISSION FACTORS, SILICA PROCESSING

Process	Emission factors (kg/tonne of throughput)
	Particulate Matter
CRUSHING OPERATIONS	
Primary crushing	0.25
Secondary crushing and screening	0.75
Recrushing and screening	2.5
Fines mills	3.0
MISCELLANEOUS OPERATIONS	
Screening, conveying and handling	1.0
Storage pile losses	0.19

TABLE 34 TOTAL EMISSIONS, SILICA PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	15				
Prince Edward Island					
Nova Scotia	13				
New Brunswick					
Quebec	465				
Ontario	619				
Manitoba	366				
Saskatchewan	64				
Alberta	73				
British Columbia	13				
Yukon, N.W.T.					
TOTAL CANADA	1 628				

* Expressed as SO₂** Expressed as NO₂

Stone can be produced in a large variety of sizes such as building stone, pulverized stone, crushed stone, and rubble and riprap. Crushed stone accounted for about 85% of total stone production in Canada in 1976.

2.21.2 Emission Sources. Dust emissions occurred from all the above unit operations, as well as from storage piles, and from conveying and drying operations.

2.21.3 Controls. A control efficiency of 95% was attained by using baghouses except for material handling and storage pile losses. An efficiency of 70% was assumed for the handling operation.

2.21.4 Emissions. Data on the production of stone by province and by type were obtained from the literature (88). An emission factor for the production of building stone was estimated by the Air Pollution Control Directorate. All other emission factors were based on U.S. Environmental Protection Agency publications (1, 54). Storage pile losses were computed using a form of the Thornthwaite Moisture Index (7).

Emission factors and total emissions for stone processing are listed in Tables 35 and 36 respectively.

2.22 Sand And Gravel Processing

2.22.1 Process Description. Sand and gravel deposits are quarried, transported to the plant and then washed, crushed, screened and stockpiled.

2.22.2 Emission Sources. The major sources of particulate emissions were the screening and crushing operations.

2.22.3 Controls. Control measures normally consisted in wetting the material to minimize dusting during handling operations. It was assumed that no control equipment was used for particulate emissions from the crushing and screening operations.

2.22.4 Emissions. Emissions were calculated using an uncontrolled particulate emission factor of 0.05 kg/tonne (6) and pertinent data on shipments of sand and gravel (34).

Estimated total particulate emissions attributable to sand and gravel processing are presented in Table 37.

2.23 Mining and Rock Quarrying

2.23.1 Process Description. The metal mining and stone quarrying industries handle large volumes of a variety of materials, mostly rock, using various techniques.

TABLE 35 UNCONTROLLED EMISSION FACTORS, STONE PROCESSING

Process	Emission factors (kg/tonne of throughput)
	Particulate Matter
BUILDING STONE	
Cutting, etc.	1.0
PULVERIZED STONE	
Primary crushing	0.28
Secondary crushing and screening	0.07
Recrushing and screening	2.5
Fines mills	3.0
Screening, conveying and handling	1.0
Storage pile losses	0.16
CRUSHED STONE	
Primary crushing	0.25
Secondary crushing	0.12
Screening, conveying and handling	1.0

Mining operations are carried out underground or in an open-pit while stone quarrying is always an open-pit operation. Regardless of the operation, the methods used for rock removal are similar. The rock is drilled, blasted, loaded and transported to a crushing site via trucks or conveyors. In open-pit mining, overburden material has to be removed to expose the rock.

2.23.2 Emission Sources. Drilling, blasting, loading and transporting create dust emissions. In underground mining, the emissions are naturally lower than from open-pit mines. However, particulates are nonetheless emitted through the ventilation systems.

Blasting agents also generate nitrogen oxides and some hydrocarbons, but do not contribute significantly to the pollution burden.

Emissions from iron ore, coal and salt mining were dealt with in their respective sectors.

2.23.3 Controls. Dust emissions are controlled to some extent by water spraying when operating conditions are dry.

TABLE 36 TOTAL EMISSIONS, STONE PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	111				
Prince Edward Island					
Nova Scotia	502				
New Brunswick	1 034				
Quebec	12 296				
Ontario	8 654				
Manitoba	458				
Saskatchewan					
Alberta	140				
British Columbia	824				
Yukon, N.W.T.					
TOTAL CANADA	24 019				

* Expressed as SO₂** Expressed as NO₂

2.23.4 Emissions. Mine production quantities were obtained from the literature (105, 106). Emission factors for mining operations were taken from a U.S. Environmental Protection Agency publication (107). A particulate emission factor of 0.05 kg/tonne was used for underground mining, whereas 0.51 kg/tonne was used for open-pit mining. Gaseous emissions from blasting were assumed to be negligible (2).

Total emissions for mining and rock quarrying are summarized in Table 38.

2.24 Sulphate (Kraft) Pulping

2.24.1 Process Description. The sulphate (kraft) process is used to produce most of the pulp in Canada and involves the 'cooking' of wood chips under pressure in an aqueous solution of sodium hydroxide and sodium sulphide. The slurry of pulp fibres from the cooking process is washed to recover dissolved wood and spent pulping chemicals. The fibre slurry passes through a knotter, where unreacted chunks of wood are removed. A large portion of the wood pulp is then bleached, before being pressed and dried into the finished product. The spent liquor from the washers, known as black liquor, contains the

TABLE 37 TOTAL EMISSIONS, SAND AND GRAVEL PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	248				
Prince Edward Island	39				
Nova Scotia	420				
New Brunswick	284				
Quebec	3 858				
Ontario	3 440				
Manitoba	806				
Saskatchewan	431				
Alberta	1 226				
British Columbia	1 705				
Yukon, N.W.T.					
TOTAL CANADA	12 457				

* Expressed as SO_2

** Expressed as NO_2

cooking chemicals and about half the original water in the wood. It is evaporated to remove most of the water and sprayed into a recovery boiler, where its organic content supports combustion. The inorganic compounds are withdrawn as a molten smelt which is then processed to produce pulping chemicals to be recycled in the process.

2.24.2 Emission Sources. Several steps in the pulping and chemical recovery process resulted in the production of significant quantities of air emissions. The major emission sources were the recovery boiler, the smelt dissolving tank and the lime kiln.

The contaminants considered for these sources were particulate matter, sulphur oxides, nitrogen oxides and carbon monoxide.

2.24.3 Controls. Most of the kraft pulping plants in Canada had some type of air pollution control equipment. Electrostatic precipitators on recovery furnaces and wet scrubbers on lime kilns were the most widely used. Smelt dissolving tanks had mesh pads (usually with intermittent showers). All kraft pulp mills in Canada operated chemical recovery systems.

TABLE 38 TOTAL EMISSIONS, MINING AND ROCK QUARRYING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	5 581				
Prince Edward Island					
Nova Scotia	3 152				
New Brunswick	1 539				
Quebec	66 982				
Ontario	6 468				
Manitoba	599				
Saskatchewan	4 695				
Alberta	939				
British Columbia	29 688				
Yukon	1 930				
N.W.T.	1 968				
TOTAL CANADA	123 541				

* Expressed as SO₂

** Expressed as NO₂

2.24.4 Emissions. Production figures from kraft pulping operations were obtained from various questionnaires (7, 28). Controlled emission factors, except for nitrogen oxides, were developed by the Air Pollution Control Directorate. The types of control equipment used and their efficiencies were obtained from industrial questionnaire replies. The nitrogen oxides emission factor was based on an EPA report (27). Sulphur dioxide emissions from Alberta were obtained from an Alberta Environment report (26).

Emission factors and total emissions for sulphate (kraft) pulping are listed in Tables 39 and 40 respectively.

2.25 Sulphite Pulping

2.25.1 Process Description. Sulphite pulping is accomplished by heating wood chips under pressure in an aqueous solution of cooking liquor to produce a fibrous slurry. The cooking liquor, or acid, is produced by burning sulphur and absorbing the sulphur dioxide in an alkaline base solution such as carbonate or hydroxide of calcium, magnesium, sodium or

TABLE 39 CONTROLLED EMISSION FACTORS, SULPHATE (KRAFT) PULPING

Process	Emission factors (kg/ADMT pulp*)			
	Particulate Matter**	Sulphur oxides***	Nitrogen oxides****	Carbon monoxide
Recovery boiler		2.5	0.95	1.5
Smelt dissolving tank				
Lime kiln			0.75	0.5

* ADMT: air dried metric ton

** Particulate emission factors calculated separately for each plant.

*** Expressed as SO₂**** Expressed as NO₂

TABLE 40 TOTAL EMISSIONS, SULPHATE (KRAFT) PULPING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	338	556	378		445
Prince Edward Island					
Nova Scotia	3 251	401	273		321
New Brunswick	8 830	1 522	1 005		1 198
Quebec	19 064	3 555	2 271		2 747
Ontario	12 523	3 669	2 495		2 935
Manitoba	850	357	243		286
Saskatchewan	3 553	550	374		440
Alberta	3 043	10 001	728		859
British Columbia	46 169	10 919	7 425		8 736
Yukon					
N.W.T.					
TOTAL CANADA	97 621	31 530	15 192		17 967

* Expressed as SO₂** Expressed as NO₂

ammonia. Before the raw acid is used in pulping it is fortified with relief gases of sulphur dioxide from the digester. Upon completion of the cooking cycle the contents of the digester are discharged into a blow tank. The pulp then goes through a washing stage, where spent liquor is separated from the fibres and cleaned, before being bleached or used directly in the end products.

2.25.2 Emission Sources. Sulphur oxides were the principal contaminant from the sulphite process and originate from the cooking and acid-making operations. The major sources of emissions were the absorption towers, blow pits or dump tanks, and spent sulphite liquor combustion units when chemical recovery systems were used.

2.25.3 Controls. Most of the sulphite pulping facilities were old and small and have very little emission control equipment. Blowing emissions from the digester were inadequately controlled by the water showers in the blow tank vents. Four plants had chemical recovery systems in 1976, three bisulphite plants and one acid sulphite plant. Control in the recovery boiler was carried out by flue-gas scrubbers, the primary purpose of which was recovering sulphur dioxide for cooking acid manufacture.

2.25.4 Emissions. Production figures from sulphite pulping operations were obtained from the literature (98). Uncontrolled emission factors were estimated internally and were based on a U.S. Environmental Protection Agency publication and reported industry data (1, 29). An average emission factor of 22.5 kg SO_x /ADMT pulp was used for acid sulphite plants with chemical recovery and 43.5 kg SO_x /ADMT without chemical recovery. For bisulphite plants, an emission factor of 22.5 kg/ADMT was used for both plants with and without recovery furnaces.

Emission factors and total emissions for sulphite pulping are given in Tables 41 and 42 respectively.

2.26 Sulphuric Acid Production

2.26.1 Process Description. Sulphuric acid may be produced from sulphur dioxide contained in smelter off-gases or from the burning of elemental sulphur. Emissions from acid plants used in smelters are dealt with in other sections.

All sulphuric acid in Canada is produced by the Contact process. The first stage involves the production of a clean, dry gaseous mixture of sulphur dioxide and air. The dried gas mixture is then preheated and passed through a catalytic converter to form sulphur trioxide. This is absorbed into a weak sulphuric acid to produce the concentrated product.

TABLE 41 UNCONTROLLED EMISSION FACTORS, SULPHITE PULPING

Process	Emission factors (kg/ADMT pulp*)		
	Particulate matter	Sulphur oxides***	
		Acid sulphite pulp	Bisulphite pulp
Digester discharge		33.5	12.5
Absorption tower		5-10 ^a	5-10 ^a
SSL** combustion	2.5	10-15 ^a	10-15 ^a
Miscellaneous		2.5	2.5

* ADMT: air dried metric ton

** SSL: spent sulphite liquor

*** Expressed as SO₂

a After primary scrubbing

TABLE 42 TOTAL EMISSIONS, SULPHITE PULPING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland		3 031			
Prince Edward Island					
Nova Scotia	337	3 636			
New Brunswick		9 229			
Quebec	388	28 605			
Ontario	231	12 440			
Manitoba		606			
Saskatchewan					
Alberta					
British Columbia		8 924			
Yukon, N.W.T.					
TOTAL CANADA	956	66 471			

* Expressed as SO₂** Expressed as NO₂

2.26.2 Emission Sources. The major source of emissions was the waste gas from the absorber exit stack. Significant emissions may also have occurred from storage tanks and acid concentrators.

Sulphur dioxide emitted from the process, as well as acid mist escaping from the absorption tower, were the contaminants considered.

2.26.3 Controls. It was assumed that all plants had recovery equipment. Conversion of SO_2 to SO_3 varied between 95% and 99.7% (dual absorption process).

2.26.4 Emissions. Total production of sulphuric acid was obtained from a Statistics Canada publication (30). The quantity of sulphuric acid produced by acid plants located at smelters in 1976, as given in the literature (31), was subtracted from the total production figure. Emission data was obtained from questionnaires where available and emission factors assuming 98% conversion were applied in other cases (1, 28). These emission factors were used to calculate emissions on a plant basis.

Total emissions from sulphuric acid production are given in Table 43.

TABLE 43 TOTAL EMISSIONS, SULPHURIC ACID PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec		321			
Ontario		1 712			
Manitoba		761			
Saskatchewan		276			
Alberta		4 811			
British Columbia		185			
Yukon, N.W.T.					
TOTAL CANADA		8 066			

* Expressed as SO_2

** Expressed as NO_2

2.27 Nitric Acid Production

2.27.1 Process Description. The ammonia oxidation process was the principal method of producing nitric acid in Canada in 1976. It involves the high-temperature oxidation of ammonia with air in the presence of a platinum catalyst to form nitric oxide. After cooling, additional air is required to complete the oxidation to nitrogen dioxide. The product is absorbed with water to form a weak nitric acid, which can be consumed or further concentrated by treating it with strong sulphuric acid.

2.27.2 Emission Sources. The main source of nitrogen oxides was the tail gas from the acid absorption tower. Small amounts are also emitted from the acid concentrators and storage tanks.

2.27.3 Controls. The control of nitrogen oxides depends on the age of the acid plant. New plants have greatly decreased emissions, with more efficiently designed absorption towers and nitric acid plants. It was assumed that approximately 50% of the national production of nitric acid takes place in modern plants.

2.27.4 Emissions. The 1976 production of nitric acid on a national basis was estimated using either questionnaire information on production from other years or obtained from unpublished information (7, 28, 47). Emissions were calculated from the questionnaire data given (7, 28).

Total emissions for nitric acid production are presented in Table 44.

2.28 Potash Processing

2.28.1 Process Description. The main source of potash is the mineral sylvite, which is usually found in association with halite (NaCl) and is mined either by underground excavation or by solution extraction. Broken rock or potash-rich solutions are transferred to the surface plant where further refining, by flotation or evaporation and crystallization, takes place. Rock mined by conventional excavation methods is crushed and the sylvite is removed by flotation. It is then dried and screened to provide different grades of potassium chloride. Evaporation and crystallization refining processes are mainly used for solution-mining methods. Only one plant in Canada used solution-mining methods in 1976.

2.28.2 Emission Sources. Potash is mined underground; however, this section covers only above-ground processing. This includes crusher and grinder, product dryer, product sizing and handling and product storage and loading. Finely divided salt particulates

TABLE 44 TOTAL EMISSIONS, NITRIC ACID PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec			310		
Ontario			1 230		
Manitoba			556		
Saskatchewan					
Alberta			5 392		
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA			7 488		

* Expressed as SO₂** Expressed as NO₂

produced in the refining process, particularly during drying and screening operations, are the major problem.

Particulate matter was the only contaminant considered for this industry.

2.28.3 Controls. Wet scrubbers and cyclones were the most common control devices used for the product dryers and crushing and grinding operations. Mechanical collectors, scrubbers and baghouses were used in other plant operations.

2.28.4 Emissions. Particulate emissions were calculated based on source sampling data for the year 1979 (89) and production data were obtained from the literature (89, 92).

Total emissions attributable to the potash processing industry are given in Table 45.

2.29 Phosphate Rock Processing

2.29.1 Process Description. Mined ore is usually beneficiated, crushed and categorized according to the purchaser's specifications. These intermediate steps in the

TABLE 45 TOTAL EMISSIONS, POTASH PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario					
Manitoba					
Saskatchewan	20	207			
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	20	207			

* Expressed as SO₂

** Expressed as NO₂

mining of phosphate rock are not included in this assessment because all the phosphate rock used in Canada is imported, and upgrading of the rock is usually done at the mine. Similarly, drying of phosphate rock is usually carried out at the mine.

Of concern here is the fact that most fertilizer and elemental phosphorus plants grind the phosphate rock prior to its use in fertilizer and elemental phosphorus production.

2.29.2 Emission Sources. Emissions in the form of fine rock dust occur mainly from grinding and material-handling operations.

2.29.3 Controls. It was assumed that grinding operations were controlled at an average efficiency of 97% but transfer and storage operations were considered to be uncontrolled.

2.29.4 Emissions. Emission factors were taken from a U.S. Environmental Protection Agency publication (1), with some adjustments made to account for Canadian conditions. Because most of the phosphate rock in Canada is stored in sheds, the storage pile emission

factor was estimated at 0.5 kg/tonne. The quantities of phosphate rock used in each province were estimated based on questionnaire data, engineering judgment and Statistics Canada publications (28, 33, 101).

Emission factors and total emissions for phosphate rock processing are presented in Tables 46 and 47 respectively.

2.30 Phosphate Fertilizer Production

2.30.1 Process Description. Phosphate fertilizers are produced by decomposing phosphate rock with a strong mineral acid.

Single superphosphate is the product of acidulation of phosphate rock with sulphuric acid and involves three basic steps. Acid and phosphate rock are mixed, dropped into a curing den, held for sufficient time to allow the slurry to set into a solid porous form and stored to permit the acidulation to go to completion. After the curing period, the product is usually granulated and dried.

The production of triple superphosphate is similar to that of single superphosphate, the only difference being that phosphoric acid is used for acidulation.

Ammonium phosphates are produced when phosphoric acid is treated or neutralized with ammonia under controlled conditions. The material is then dried and cooled prior to screening.

There were 9 companies producing phosphate fertilizers in 1976 from a total of 13 plants.

2.30.2 Emission Sources. The major sources of particulate emissions are the granulators, dryers, coolers and screens. There are also gases released from the acid/phosphate rock reaction tanks which contain mainly silicon tetrafluorides, carbon monoxide and some particulates; however, due to a lack of information, emissions could not be estimated for this source.

2.30.3 Controls. All phosphate fertilizer manufacturing plants had some type of air pollution control equipment. Granulation, drying and cooling operations were usually controlled by wet scrubbers and baghouses with an average control efficiency of 95%.

2.30.4 Emissions. Emissions from ammonium phosphate fertilizer plants were calculated using production figures from industrial questionnaire replies and published emission factors (1, 90). Emission factors for single and triple superphosphate manufacture were based on data from the U.S. Environmental Protection Agency (1). Production figures for each plant were estimated using information from various sources (7, 35, 28).

TABLE 46 UNCONTROLLED EMISSION FACTORS, PHOSPHATE ROCK PROCESSING

Process	Emission factors (kg/tonne rock)
	Particulate Matter
Grinding	10.0
Transfer and storage	1.0
Enclosed storage piles	0.5

TABLE 47 TOTAL EMISSIONS, PHOSPHATE ROCK PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	555				
Prince Edward Island					
Nova Scotia					
New Brunswick	669				
Quebec	558				
Ontario	916				
Manitoba					
Saskatchewan					
Alberta	1 222				
British Columbia	226				
Yukon, N.W.T.					
TOTAL CANADA	4 146				

* Expressed as SO₂

** Expressed as NO₂

At one plant, since phosphate rock arrives pre-pulverized (28), appropriate emission factors were applied.

Emission factors and total emissions for phosphate fertilizer production are listed in Tables 48 and 49 respectively.

TABLE 48 UNCONTROLLED EMISSION FACTORS, PHOSPHATE FERTILIZER PRODUCTION

Source	Emission factors (kg/tonne of product)	
	Particulate Matter	
	Ammonium Phosphates	Superphosphates
Rock pulverizing	3	3
Material handling	1	1
Screening	1	1
Ammoniator-granulator	15	-
Drying	27.5	52.5
Cooling	-	45.0
Product grinding	-	0.25

2.31 Elemental Phosphorus Production

2.31.1 Process Description. The production of elemental phosphorus involves two main operations: feed preparation and smelting of phosphate rock.

Phosphate rock is finely ground, wetted and pelletized. The pellets are fired in a kiln, cooled and stored. The other components of the furnace feed, coke and silica, undergo only cleaning and drying.

Elemental phosphorus is produced by smelting the pellets with coke and silica in an electric furnace. A slag of calcium silicate and ferrophosphorus is periodically tapped from the furnace. Phosphorus vapour is condensed and stored under water, whereas carbon monoxide is either flared or used as a fuel in preparing the furnace charge.

There were two plants producing elemental phosphorus in Canada in 1976. One of them pelletized the phosphate rock for both plants.

TABLE 49 TOTAL EMISSIONS, PHOSPHATE FERTILIZER PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick	265				
Quebec	252				
Ontario	729				
Manitoba	202				
Saskatchewan					
Alberta	2 020				
British Columbia	599				
Yukon, N.W.T.					
TOTAL CANADA	4 067				

* Expressed as SO₂

** Expressed as NO₂

2.31.2 Emission Sources. In the feed preparation area, the exhaust gas from the pelletizer plant is a major source of particulate emissions. Significant emissions also occur from the coke and silica drying plant, from the screening of coke and transfer points, and from feed proportioning.

2.31.3 Controls. Both plants had some type of air pollution control equipment. Silica/coke drying operations were controlled by cyclones, whereas emissions from the pellet plant were controlled by scrubbers and a baghouse.

Exhaust gases from the electric furnace, containing phosphorus vapour, carbon monoxide and dust, were passed through an electrostatic precipitator or scrubbed at one plant, while the other one was uncontrolled.

2.31.4 Emissions. Industrial questionnaire replies provided information on plant production as well as pollution control equipment for calculating particulate emissions (7). Sulphur dioxide emissions were obtained from Environment Canada regional offices (47).

Total emissions attributable to elemental phosphorus production are presented in Table 50.

TABLE 50 TOTAL EMISSIONS, ELEMENTAL PHOSPHORUS PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	3 534	689			
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	5 023	1 047			
Ontario					
Manitoba					
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	8 557	1 736			

* Expressed as SO_2

** Expressed as NO_2

2.32 Nitrate Fertilizer Production

2.32.1 Process Description. The basic material used in the production of nitrate fertilizer is anhydrous ammonia.

Ammonia nitrate is produced by neutralizing nitric acid with ammonia, with subsequent concentration by evaporation. The resulting solution is then formed into granules by the use of prilling towers or by ordinary granulators. It was assumed that only 9% of total production is by the granulation process (28).

Another nitrate fertilizer, urea, is produced by reacting liquid ammonia and liquid carbon dioxide at relatively high pressure. The resulting liquor is dehydrated and solidified by prilling or granulating.

2.32.2 Emission Sources. Major emission sources are prilling towers and granulators. Particulate matter can also be produced in the drying, cooling and material-handling operations.

2.32.3 Controls. Wet or dry cyclones are usually used for various granulating, drying and cooling operations in order to recover valuable product. A control efficiency of 85% on particulates was assumed.

2.32.4 Emissions. Total Canadian production of ammonium nitrate and urea was obtained from the literature (35).

Production at each plant was estimated by prorating available questionnaire information to the base year 1976 (28). Emission factors were taken from a U.S. Environmental Protection Agency publication and available questionnaire data (1, 28).

Emission factors and total emissions for nitrate fertilizer are presented in Tables 51 and 52 respectively.

2.33 Grain Handling

2.33.1 Process Description. Grain elevators are primarily transfer and storage units and are classified either as primary, terminal, transfer or process elevators.

The principal function of the primary elevators is to receive grain directly from producers for either storage or forwarding, or both. At terminal elevators, cleaning, storing and treating of grain takes place prior to shipment. Each receipt or shipment is weighed and inspected. Transfer elevators generally include the same operations as terminal elevators. Process elevators are used for receipt and storage of grain for direct manufacture or processing into other products.

2.33.2 Emission Sources. The only significant air contaminant from grain elevators is particulate matter and results mainly from grain-handling operations. The amount of dust emitted during the various grain-handling operations depends upon the type of grain being handled, its quality or grade, its moisture content, the degree of enclosure at loading and unloading areas, and the extent and efficiency of dust containment systems used.

2.33.3 Controls. Dust collection systems were generally applied to most phases of grain-handling operations to reduce product and component losses. An overall control efficiency of 75% was assumed on primary and process elevators, and 90% for terminal

TABLE 51 CONTROLLED EMISSION FACTORS, NITRATE FERTILIZER PRODUCTION

Source	Emission factors (kg/tonne of product)		
	Particulate Matter		Nitrogen oxides**
	Ammonium Nitrate*	Urea	
1. Neutralizer	1.60		0.19
2. Evaporator/Concentrator	0.47	0.47	
3. Prilling Tower	3.20	0.75	
4. Dryer and Cooler	0.05	0.05	
5. Granulator	0.20	0.18	0.45
6. Dryer and Cooler	0.53		1.50
7. Bulk Loading	0.01	0.01	

* Prilling includes sources no. 1, 2, 3, 4, 7 for ammonium nitrate

Granulation includes sources no. 1, 2, 5, 6, 7 for ammonium nitrate

** Expressed as NO₂ (for ammonium nitrate only)

and transfer elevators. It was assumed that only 25% of receipts in primary elevators are dried and 10% are cleaned.

2.33.4 Emissions. Emissions from primary, terminal and transfer elevators were based on the quantities of grain received at licensed elevators. Throughput for these types of elevators was taken to be the same as receipts given in the literature (37). Grain receipts at process elevators were assumed to be in the same ratio, as grain receipts were to grain capacities for terminal and transfer elevators (40). A provincial breakdown was made on the basis of grain storage capacity of process elevators as found in pertinent literature (40). All emission factors were taken from published data (38).

Emission factors and total emissions for grain-handling operations are presented in Tables 53 and 54 respectively.

2.34 Grain Milling

2.34.1 Process Description. The grain milling industry includes establishments engaged in milling flour or meals from grain. Commercial flour milling in Canada is carried out by numerous companies.

TABLE 52 TOTAL EMISSIONS, NITRATE FERTILIZER PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	370		27		
Ontario	1 461		97		
Manitoba	362		25		
Saskatchewan					
Alberta	1 458		92		
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	3 651		241		

* Expressed as SO₂

** Expressed as NO₂

Only the milling of wheat is included in this survey. The process consists of four main operations: reception and storage of wheat, cleaning and conditioning, milling of wheat into flour and into its by-products, and storage or shipment of finished product.

2.34.2 Emission Sources. The major emission sources are wheat-cleaning and milling operations. Dust emissions associated with receiving and handling of wheat are also included.

The contaminant considered for these sources is particulate matter.

2.34.3 Controls. Due to the economic value of the products, the extent of control is high. Baghouses, 97% efficient, are used in the control of the milling operation, while either cyclones, baghouses, or no control at all was assumed for all other operations with an average efficiency of 75%. For the western mills, storage emissions were considered in Section 2.31 under process elevators, hence not considered here.

TABLE 53 UNCONTROLLED EMISSION FACTORS, GRAIN HANDLING

Process	Emission factors (kg/tonne of grain)
	Particulate Matter
PRIMARY ELEVATORS	
Unloading (receiving)	0.32
Loading (shipping)	0.135
Removal from bins	1.455
Drying	0.085
Cleaning	0.24
Headhouse (legs)	2.31
TERMINAL ELEVATORS	
Unloading (receiving)	0.50
Loading (shipping)	0.135
Removal from bins (tunnel belt)	1.42
Drying	0.055
Cleaning	0.66
Headhouse (legs)	2.275
Tripper (gallery belt)	<u>0.855</u>
	5.90
TRANSFER ELEVATORS	
(same breakdown as terminal)	5.90
PROCESS ELEVATORS	
Unloading	0.50
Headhouse (legs)	2.275
Tripper (gallery belt)	0.855
Removal from bin	<u>1.455</u>
	5.085

TABLE 54 TOTAL EMISSIONS, GRAIN HANDLING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia	372				
New Brunswick	222				
Quebec	8 370				
Ontario	9 962				
Manitoba	4 774				
Saskatchewan	13 155				
Alberta	8 140				
British Columbia	4 247				
Yukon, N.W.T.					
TOTAL CANADA	49 242				

* Expressed as SO₂

** Expressed as NO₂

2.34.4 Emissions. The capacities of grain mills for wheat were obtained from the literature (41). The mills were assumed to operate 5 days per week, 52 weeks per year. Production was estimated at 78% of capacity (37). Emission factors were based on published data and other internal sources (28, 38).

Emission factors and total emissions for grain milling are given in Tables 55 and 56 respectively.

2.35 Clay Products Manufacture

2.35.1 Process Description. The manufacture of clay products involves the mining, grinding and blending of raw materials, and the forming, cutting, drying and firing of the final product. In Canada, gas, oil and coal are normally used for kiln heating.

This sector includes emissions from the manufacturing of bricks, structural and drain tiles, clay sewer pipes, flue lining, glazed floor and wall tiles, and firebrick.

TABLE 55 UNCONTROLLED EMISSION FACTORS, GRAIN MILLING

Process	Emission factors (kg/tonne of grain received)
	Particulate Matter
Unloading	0.50
Headhouse (legs)	2.275
Tripper (gallery belt)	0.855
Removal from bin	1.455
Precleaning and handling	2.50
Cleaning house*	0.20
Millhouse	35.00

* Controlled emission factor obtained from U.S. Environmental Protection Agency (1) for "Feed and Grain Mills and Elevators".

TABLE 56 TOTAL EMISSIONS, GRAIN MILLING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia	94				
New Brunswick					
Quebec	1 528				
Ontario	2 093				
Manitoba	676				
Saskatchewan	537				
Alberta	864				
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	5 792				

* Expressed as SO₂

** Expressed as NO₂

2.35.2 Emission Sources. The major source of dust is the materials-handling operation which includes the drying, grinding, and storing of raw materials. The other contaminants are combustion products emitted mainly from the fuel consumed in kiln-firing operations.

2.35.3 Controls. Grinding and drying operations were assumed to be controlled at 96% efficiency, whereas kiln-firing operations were considered to be uncontrolled. Storage facilities for raw materials were enclosed. An overall control efficiency of 90% was assumed for the grinding and storage enclosure operations.

2.35.4 Emissions. The quantity of clay products manufactured in Canada was obtained from several publications (67, 68, 69). A listing of plants manufacturing various clay products, their capacity, and the type of fuel used was found in pertinent literature (66). Emission factors were based on data from the U.S. Environmental Protection Agency (1). Sulphur and ash content of fuels (included in the emission factors) were obtained from an internal government source (56). Emissions from kiln firing are included in Section 3.2 under Industrial Fuel Combustion.

Emission factors and total emissions for clay products manufacture are presented in Tables 57 and 58 respectively.

2.36 Crude Oil Production

2.36.1 Process Description. Crude oil is obtained from underground wells. The crude is lifted from the well by rod or submersible pump and is subsequently piped to a refinery.

Crude oil is also imported into Canada from other oil producing countries and is delivered by ocean-going vessels.

2.36.2 Emission Sources. Contaminants emitted into the ambient air are fugitive leaks. The most prevalent leaks are associated with pumps and valves; flanges and other types of connectors do not contribute significantly to the overall leak rate. Most crude oil is transported by pipeline, resulting in negligible emissions, but hydrocarbons are evolved during the unloading of ships.

2.36.3 Controls. The fugitive emissions are released without control of flow or direction and consequently no direct control can be used. Quality and degree of maintenance is the significant factor in reducing losses due to most fugitive emissions.

TABLE 57 UNCONTROLLED EMISSION FACTORS, CLAY PRODUCTS MANUFACTURE

Source	Emission factors (kg/tonne of product)
	Particulate matter
Dryer-Grinder	48.0
Storage	17.0

TABLE 58 TOTAL EMISSIONS, CLAY PRODUCTS MANUFACTURE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	71				
Prince Edward Island					
Nova Scotia	583				
New Brunswick	195				
Quebec	2 991				
Ontario	7 654				
Manitoba	42				
Saskatchewan	445				
Alberta	996				
British Columbia	514				
Yukon, N.W.T.					
TOTAL CANADA	13 491				

* Expressed as SO₂

** Expressed as NO₂

2.36.4 Emissions. Canadian crude oil production was obtained from the literature (108). Emission factors for fugitive emissions were taken from a U.S. Environmental Protection Agency publication (102).

The quantity of oil imported was supplied by the Department of Energy, Mines and Resources (23) and an emission factor of $0.275 \text{ kg}/10^3$ litres of oil unloaded was used in estimating transportation losses. Emission factors and total emissions for crude oil production are listed in Tables 59 and 60 respectively.

2.37 Petroleum Refining

2.37.1 Process Description. Refining consists of the breaking down of crude oil into a number of consumer products and involves four major processes: separation, conversion, treating, and blending.

Distillation is employed to separate crude oil into various components of different boiling ranges. Each of these fractions may then be subjected to further processing appropriate to the type and degree of refinement required in the ultimate product. Depending upon the conditions of the market, it is often necessary to chemically convert the molecular structures of certain hydrocarbons to produce more useful or high-octane products. This conversion is accomplished by catalytic reforming, cracking or polymerization of the original molecules. The final step is treating and blending; it involves filtration to remove impurities, and mixing of various flows to achieve desired specifications.

2.37.2 Emission Sources. The major emission sources are storage tanks, regenerators or catalytic cracking units, sulphur plants, and fuel-fired process heaters and boilers.

2.37.3 Controls. Hydrocarbon losses from storage tanks were controlled by use of either cone or floating roof-type tanks. Emissions of sulphur oxides were controlled through conversion to elemental sulphur in sulphur recovery plants. In the coking and converting processes, certain plants used electrostatic precipitators and carbon monoxide boilers, to reduce particulate and carbon monoxide emissions, respectively. All other operations were largely uncontrolled.

2.37.4 Emissions. Refinery throughput and capacities were obtained from both questionnaires and other available literature (7, 71, 55, 87). Emission factors obtained from the U.S. Environmental Protection Agency (1, 102) along with internally developed information (71), were used to calculate the emissions from the above-mentioned sources.

TABLE 59 EMISSION FACTORS, CRUDE OIL PRODUCTION

Source	Emission factors (kg/10 ⁶ litres production)
	Hydrocarbons
Compressor seals	11.4
Relief valves	22.8
Waste water separators	22.8
Pipeline valves	34.2
Pumps	213.8
Total	305.0

TABLE 60 TOTAL EMISSIONS, CRUDE OIL PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland				122	
Prince Edward Island					
Nova Scotia				2 369	
New Brunswick				1 593	
Quebec				1 255	
Ontario				30	
Manitoba				194	
Saskatchewan				2 693	
Alberta				21 105	
British Columbia				777	
Yukon, N.W.T.				43	
TOTAL CANADA				30 181	

* Expressed as SO₂** Expressed as NO₂

It should be noted that not all plants have all operations. Emissions from fuel combustion are included in Section 3.2 under Industrial Fuel Combustion.

Emission factors and total emissions for petroleum refining are presented in Tables 61 and 62 respectively.

TABLE 61 UNCONTROLLED EMISSION FACTORS, PETROLEUM REFINING

Process	Emission factors				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Coking ^a	1.5	-	-	-	-
Converting ^a (Catalytic cracking)	0.70	1.41	0.20	0.63	39.2
Storage Tanks ^a					
- Fixed	-	-	-	3.14	-
- Floaters	-	-	-	0.13	-
Miscellaneous ^b	-	-	-	0.63	-

* Expressed as SO₂

** Expressed as NO₂

a Emission factors expressed as kg/10³ litres fresh feed

b Controlled emission factor expressed as kg/10³ litres refinery feed.

2.38 Natural Gas Processing

2.38.1 Process Description. Natural gas processing involves the removal of hydrogen sulphide and heavy hydrocarbons from the sour gas. Hydrogen sulphide is stripped from the natural gas with an amine solution and subsequently liberated, with regeneration of the original amine solution. About 95% of the hydrogen sulphide is then recovered in sulphur plants to produce elemental sulphur, while the remainder is incinerated to sulphur dioxide and released through tall stacks.

2.38.2 Emission Sources. The major sources of sulphur oxide emissions are the sulphur plant stack and the flare. Hydrocarbons are mainly emitted from storage tanks, whereas the rest of the emissions are from fuel burning (heaters, boilers, compressors).

2.38.3 Controls. By adding a tail gas unit to the sulphur plant, emissions can be greatly reduced. In 1976 only one plant used this type of unit.

TABLE 62 TOTAL EMISSIONS, PETROLEUM REFINING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	559	8 337	334	15 740	64 504
Prince Edward Island					
Nova Scotia	1 182	10 147	347	16 058	66 966
New Brunswick		Included with Newfoundland			
Quebec	3 812	23 834	1 180	73 445	115 221
Ontario	3 073	32 660	1 190	19 221	104 500
Manitoba	241	2 203	71	4 953	13 666
Saskatchewan	551	1 712	94	14 408	
Alberta	2 078	3 177	777	13 427	23 430
British Columbia	1 233	9 901	435	16 288	62 871
Yukon, N.W.T.		Included with British Columbia			
TOTAL CANADA	12 729	91 971	4 428	173 540	451 158

* Expressed as SO₂** Expressed as NO₂

2.38.4 Emissions. Sulphur dioxide emissions from natural gas processing plants were obtained from various sources (39, 26, 71). Emission factors from the U.S. Environmental Protection Agency were used to estimate emissions of other contaminants (1), by prorating available production data (93). Emissions from fuel combustion are included in Section 3.2 under Industrial Fuel Combustion.

Total emissions attributable to natural gas processing are listed in Table 63.

2.39 Tar Sands Operations

2.39.1 Process Description. The fundamental steps in extraction of bitumen from oil sands are feed conditioning, separation of the bitumen, waste disposal, and cleaning the bitumen concentrate.

Conditioning is achieved by mixing the feed with water and caustic soda at 180°F to increase its pH value. The conditioned pulp (70% solids) is pumped to separation

TABLE 63 TOTAL EMISSIONS, NATURAL GAS PROCESSING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario		186		49	
Manitoba					
Saskatchewan		255		40	
Alberta		343 100		6 004	
British Columbia		229 190		3	
Yukon, N.W.T.					
TOTAL CANADA		572 731		6 096	

* Expressed as SO₂

** Expressed as NO₂

cells where the coarse mineral matter settles and is pumped to the tailings pond. The floating bitumen froth, rich in water and fine mineral matter, is fed to the final extraction plant.

In the final extraction, the froth is diluted with coker naphtha and directed through a centrifuge. The product is distilled to remove the coker naphtha and the water from the bitumen and is upgraded by standard methods to obtain marketable products.

2.39.2 Emission Sources. The major emission source is the power plant. The fuel to the boilers is pulverized coke and at times supplemented by heavy oil. The sulphur plant is also a source of emissions. Sour gas flaring and other miscellaneous operations also contribute to the overall emissions.

2.39.3 Controls. Particulate emissions from the boilers are controlled by electrostatic precipitators. A sulphur plant is used to recover about 95% of the sulphur charge in the sour gases from the various process streams.

2.39.4 Emissions.

Emission data were provided by Alberta Environment (109).

Total emissions from tar sands operations are presented in Table 64.

TABLE 64 TOTAL EMISSIONS, TAR SANDS OPERATIONS, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario					
Manitoba					
Saskatchewan					
Alberta	14 370	93 000	5 734	Neg.	319
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	14 370	93 000	5 734	Neg.	319

* Expressed as SO₂

** Expressed as NO₂

Neg. - Negligible

2.40 Glass Manufacturing

2.40.1 Process Description. Most of the glass produced in Canada is the soda-lime type. Its major ingredients are sand, limestone, soda ash, and cullet. The mixture of these materials is melted at high temperature (2700°F) in large, direct-fired, continuous, regenerative furnaces. After a little cooling, the product is delivered to the glass-forming machines, and then conveyed to annealing ovens for heat treatment. There are three major products made in Canada: flat glass, glass containers and pressed and blown glass, containers accounting for about 90% of the total.

2.40.2 Emission Sources. The most significant source of particulate emissions in glass production is the regenerating furnace during the melting process. Handling, mixing and

storage of raw materials, glass-forming machines and annealing ovens are minor sources of emissions of air contaminants.

2.40.3 Controls. The regenerative furnaces were generally equipped with wet centrifugal scrubbers or baghouses to control the particulates.

2.40.4 Emissions. Production figures for glass manufacturing plants in Canada were obtained from pertinent information (66, 42). Emission factors for each product formed were obtained from various U.S. Environmental Protection Agency publications (32, 99, 100). Plants were assumed to operate an average of 350 days per year.

Emission factors and total emissions from glass manufacturing are listed in Tables 65 and 66 respectively.

TABLE 65 CONTROLLED EMISSION FACTORS, GLASS MANUFACTURING

Source	Emission factors (kg/tonne of product)
	Particulate Matter
Flat glass	1.0
Glass containers	0.68
Pressed and blown glass	8.7

2.41 Concrete Batching

2.41.1 Process Description. Sand, gravel and cement are proportioned by means of weigh hoppers and conveyors and discharged with water into a mixing receiver such as a transit-mix truck. The batch product is then transported to the construction site for building purposes.

2.41.2 Emission Sources. Particulates are released during the concrete batching operations such as material handling, loading, conveying, mixing and unloading. Movement of trucks over dusty surfaces at the site is another source of dust emissions.

2.41.3 Controls. A control efficiency of 60% was used for the province of Saskatchewan (89). For the remainder of Canada, an overall control efficiency of 75% was assumed.

TABLE 66 TOTAL EMISSIONS, GLASS MANUFACTURING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick	28				
Quebec	310				
Ontario	833				
Manitoba					
Saskatchewan					
Alberta	36				
British Columbia	71				
Yukon, N.W.T.					
TOTAL CANADA	1 278				

* Expressed as SO_2

** Expressed as NO_2

2.41.4 Emissions. Production figures for concrete batching plants were obtained from the literature (43, 44). An emission factor was based on a U.S. Environmental Protection Agency publication (1).

Emission factors and total emissions from concrete batching are listed in Tables 67 and 68 respectively.

2.42 Magnesium Production

2.42.1 Process Description. A silicothermic process (Pidgeon process) was used by the only plant that produced primary magnesium in Canada in 1976. The process consists of two steps:

- (1) The high quality dolomite is calcined in a rotary kiln
- (2) The resulting product "dolime" is mixed with ferrosilicon and charged into retorts for external heating under high vacuum and high temperature. The magnesium

TABLE 67 UNCONTROLLED EMISSION FACTORS, CONCRETE BATCHING

Source	Emission factors (kg/m ³)
	Particulate Matter
Concrete batching	0.12

TABLE 68 TOTAL EMISSIONS, CONCRETE BATCHING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	5				
Prince Edward Island	5				
Nova Scotia	8				
New Brunswick	7				
Quebec	106				
Ontario	176				
Manitoba	11				
Saskatchewan	31				
Alberta	61				
British Columbia	45				
Yukon, N.W.T.					
TOTAL CANADA	455				

* Expressed as SO₂** Expressed as NO₂

content is reduced and collected on the lining of a condenser, and the condensate is then remelted and cast into ingots of magnesium.

2.42.2 Emission Sources. Particulates are the only contaminants considered and result from calcining and drying of the dolomite.

2.42.3 Controls. A control efficiency of 90% was attained using multiclones (7).

2.42.4 Emissions. A controlled emission factor of 2.2 kg/tonne has been assumed for the drying operation (49), with production data available from questionnaires (7, 45). Calcining emissions were calculated from questionnaire data (7).

Emissions from magnesium production are listed in Table 69.

TABLE 69 TOTAL EMISSIONS, MAGNESIUM PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario	251				
Manitoba					
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	251				

* Expressed as SO₂

** Expressed as NO₂

2.43 Phosphoric Acid Production (Thermal Process)

2.43.1 Process Description. Phosphate rock, siliceous flux and coke are heated in an electric furnace to produce elemental phosphorus, which may then be burned and hydrated to form high-purity phosphoric acid (H_3PO_4) for industrial uses.

Only one plant manufactured thermal phosphoric acid in Canada in 1976.

2.43.2 Emission Sources. The major emission from thermal phosphoric acid is P_2O_5 acid mist from the absorber tail gas.

2.43.3 Controls. A scrubber and cyclone were used to control particulate emissions, with a 93% efficiency (7).

2.43.4 Emissions. Production figures for phosphoric acid (thermal process) were obtained from an internal source (7), from which emissions were calculated.

Emissions from thermal process phosphoric acid production are listed in Table 70.

TABLE 70 TOTAL EMISSIONS, PHOSPHORIC ACID PRODUCTION (THERMAL PROCESS), 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec	67				
Ontario					
Manitoba					
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	67				

* Expressed as SO_2

** Expressed as NO_2

2.44 Carbon Black

2.44.1 Process Description. In Canada, carbon black is produced by either the furnace or the thermal process. In the furnace process, natural gas is injected into a reactor with a limited supply of combustion air. The combustion gases are then rapidly cooled to about 500°F. The carbon black is removed from the cool gases with the use of electrostatic precipitators, cyclones, and baghouses.

In the thermal process, natural gas is decomposed at about 3000°F in the absence of air and flame. The gas is then cooled and the carbon black is removed as in the furnace process.

2.44.2 Emission Sources. The combustion gases are the only source of process emissions, since the off-gas control equipment is an integral part of the process.

2.44.3 Controls. Particulate emissions are very low since the particulate in the gas is also the product, carbon black; hence very efficient controls are used.

In the thermal process the gaseous products are recycled which renders the atmospheric emissions insignificant.

2.44.4 Emissions. The total production of carbon black was estimated using published data (110). Production of carbon black by the furnace process was obtained by prorating individual plant capacities (111). The emission factors on a per plant basis were developed internally using questionnaire data (7).

Total emissions from production of carbon black are listed in Table 71.

2.45 Salt Production

2.45.1 Process Description. In Canada, three different methods of salt production are employed. About three-quarters of the total salt output is mined. The salt rock is removed from the earth, crushed, screened and packaged.

Fine vacuum salt and recovery of salt from brine are the other two methods of production. In each case, the salt is passed through dryers and subsequently crushed and screened.

2.45.2 Emission Sources. Crushing, screening, and handling operations all generate particulate emissions. The production of fine vacuum salt and salt from brine have particulate emissions generated by the dryers.

2.45.3 Controls. Particulate emissions are controlled by fabric filters.

TABLE 71 TOTAL EMISSIONS, CARBON BLACK, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario	10	1 358	Neg.	61	87 812
Manitoba					
Saskatchewan					
Alberta					
British Columbia					
Yukon, N.W.T.					
TOTAL CANADA	10	1 358	Neg.	61	87 812

* Expressed as SO₂** Expressed as NO₂

Neg. - Negligible

2.45.4 Emissions. The production of salt was obtained from published literature (112). The emission factor for mined salt was assumed to be similar to the one for "Stone Quarrying and Processing" as reported by the U.S. Environmental Protection Agency (1). The emission factor for the other methods of salt production was assumed to be 2.19 kg/t, which was developed internally and is equivalent to that used in the potash industry (28).

Emission factors and total emissions from salt production are summarized in Tables 72 and 73 respectively.

TABLE 72 CONTROLLED EMISSION FACTORS, SALT PRODUCTION

Process	Emission factors (kg/tonne of salt production)
	Particulate Matter
Primary crushing	0.05
Secondary crushing and screening	0.30
Screening, conveying and handling	1.0
Total	1.35

TABLE 73 TOTAL EMISSIONS, SALT PRODUCTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	-				
Prince Edward Island	-				
Nova Scotia	1 365				
New Brunswick	-				
Quebec	-				
Ontario	6 786				
Manitoba	59				
Saskatchewan	611				
Alberta	650				
British Columbia	-				
Yukon, N.W.T.	-				
TOTAL CANADA	9 471				

* Expressed as SO₂** Expressed as NO₂

3 EMISSIONS FROM FUEL COMBUSTION - STATIONARY SOURCES

Fuel consumption data are grouped into categories of power generation by utilities, industrial use, commercial use, and residential use.

3.1 Power Generation by Utilities

3.1.1 General. This sector encompasses emissions from the generation of electricity by publicly and privately owned utilities. Power generation by sources other than utilities is covered under the appropriate fuel type.

There are two basic methods of generating thermal power from fossil fuels: steam generating systems and internal combustion systems (gas turbine and reciprocating engines). Steam turbine boilers may be fired by coal, heavy fuel oil, crude oil or natural gas (initial steam may be raised by light fuel oil or natural gas). Gas turbines may be fired by light oil, natural gas, kerosene or diesel oil, whereas reciprocating engines may be fuelled by light oil, natural gas, a combination of both, or by diesel oil.

3.1.2 Emissions. Most of the information on fuel consumption, ash and sulphur content of fuel consumed, and the type of control used were obtained within the Air Pollution Control Directorate (46).

The basis for calculating emissions from utilities was questionnaire replies (7, 46), supplemented by figures compiled by Statistics Canada (50). For the province of Alberta, the particulate and nitrogen oxide emissions data were supplied by Alberta Environment (109). Emission factors were either taken from a U.S. Environmental Protection Agency publication (1), or developed internally for Canadian conditions (46). Power generation utilities generally had emission control equipment for particulates with a wide range of efficiencies. Several old stations were uncontrolled.

Total emissions attributable to power generation by utilities are given in Table 74.

3.2 Industrial Fuel Combustion

3.2.1 General. This section estimates the emissions resulting from the combustion of fuels in industrial establishments. The fuels included are natural gas, heavy fuel oil, light fuel oil, stove oil and kerosene, butane, propane and coal.

3.2.2 Emissions. Fuel consumption quantities were available on a provincial basis from Statistics Canada publications (51, 52, 53, 65). Ash and sulphur content of fuels used

TABLE 74 TOTAL EMISSIONS, POWER GENERATION BY UTILITIES, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	498	5 464	1 929	133	456
Prince Edward Island	463	5 914	2 219	20	112
Nova Scotia	20 816	92 622	29 432	514	1 975
New Brunswick	6 781	53 731	9 133	113	511
Quebec	282	1 908	2 006	176	580
Ontario	7 518	387 220	89 949	1 223	4 574
Manitoba	4 534	7 558	7 802	227	755
Saskatchewan	37 593	26 675	29 468	545	1 889
Alberta	108 244	32 398	29 654	953	3 495
British Columbia	197	387	2 257	202	662
Yukon, N.W.T.	234	446	2 605	243	790
TOTAL CANADA	187 160	614 323	206 454	4 349	15 799

* Expressed as SO₂** Expressed as NO₂

in various provinces were obtained from the literature (55) or elsewhere (56). Emission factors were taken from a U.S. Environmental Protection Agency publication (1).

Given the limited amount of data available and conflicting information sources, it was not possible to estimate the emissions in this sector for individual processes other than petroleum refining, natural gas processing and clay products manufacture. For these processes, the appropriate emission factors and corresponding emissions have been shown separately. It should be noted that in Table 77, the emissions totals shown represent the emissions for the whole industrial fuel combustion sector including those for petroleum refining, natural gas processing and clay products manufacture.

Emission factors and emissions due to industrial fuel combustion are presented in Tables 75 to 80.

TABLE 75 UNCONTROLLED EMISSION FACTORS, INDUSTRIAL FUEL COMBUSTION (FOR UNIDENTIFIED INDUSTRIAL SOURCES)

Source	Emission factors (kg/10 ³ litres)					
	Particulate matter		Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Natural Gas ^a	160		9.6	2800	48	272
Propane ^d	0.20		0.00366	1.35	0.036	0.18
Butane ^d	0.22		0.00366	1.45	0.036	0.19
Light fuel oil ^e	0.25	E. Canada	8.5	2.8	0.12	0.63
		W. Canada	5.1			
Heavy fuel oil ^e						
	E. Canada	3.505	E. Canada	47.5	11.25	0.12
	W. Canada	2.88	W. Canada	38.0		
Stove oil and kerosene ^e	0.25	E. Canada	8.5	2.8	0.12	0.63
		W. Canada	5.1			
Coal ^b	10.4-19.5 ^c		11.4-133.0 ^c	7.5	0.5	1.0

* Expressed as SO₂

** Expressed as NO₂

a Emission factors expressed as kg/10⁶ m³

b Emission factors expressed as kg/tonne

c Emission factors vary by province, depending upon the ash and sulphur content of coals used.

d From reference (1) under "Liquefied Petroleum Gas Consumption"

e From reference (1) under "Fuel Oil Combustion"

TABLE 76 UNCONTROLLED EMISSION FACTORS, INDUSTRIAL FUEL COMBUSTION (FOR IDENTIFIED INDUSTRIAL SOURCES)

Fuel	Source	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Natural Gas	Clay Products Manufacture: ^a					
	- Tunnel Kilns	0.02	-	0.08	0.01	0.02
	- Periodic Kilns	0.05	-	0.21	0.02	0.05
	Natural Gas Processing ^b	5.22	4.16	338.7	8.73	-
Heavy Fuel Oil	Clay Products Manufacture: ^a					
	- Tunnel Kilns	0.30	5.0	0.55	0.05	-
	- Periodic Kilns	0.45	7.4	0.85	0.05	-
Coal	Clay Products Manufacture: ^a					
	- Tunnel Kilns	5.0	7.2	0.45	0.30	0.95
	- Periodic Kilns	8.0	12.0	0.70	0.45	1.6
Fuel Gas	Petroleum Refineries ^c	0.32	9.6	3.7	0.05	0.32
Fuel Oil	Petroleum Refineries ^d	2.4	48.0	8.3	0.12	0.60

* Expressed as SO₂

** Expressed as NO₂

a Emission factors expressed as kg/tonne of product.

b Emission factors expressed as kg/10⁶ m³ of gas processed.

c Emission factors expressed as kg/10³ m³ of fuel gas burned.

d Emission factors expressed as kg/10³ litres of fuel oil burned.

TABLE 77 TOTAL EMISSIONS, INDUSTRIAL FUEL COMBUSTION, 1976

Province	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	2 220	34 172	8 037	262	343
Prince Edward Island	546	7 414	1 768	20	103
Nova Scotia	6 223	89 204	20 966	421	1 058
New Brunswick	6 475	87 090	19 995	432	1 058
Quebec	22 193	251 856	62 702	1 936	3 579
Ontario	18 982	194 817	77 081	1 952	5 418
Manitoba	3 114	10 810	5 740	223	513
Saskatchewan	1 019	4 182	6 336	161	458
Alberta	2 350	14 378	144 732	1 701	1 113
British Columbia	4 963	57 978	23 406	820	1 320
Yukon, N.W.T.	95	1 410	517	15	64
TOTAL CANADA	68 180	753 311	371 280	7 943	15 027

* Expressed as SO₂** Expressed as NO₂

TABLE 78 FUEL COMBUSTION EMISSIONS, PETROLEUM REFINING, 1976

Province	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	484	10 360	2 360	195	
Prince Edward Island	-	-	-	-	
Nova Scotia	602	12 748	2 776	215	
New Brunswick	516	11 104	2 570	217	
Quebec	2 840	51 409	12 264	1 096	
Ontario	2 476	51 563	10 591	751	
Manitoba	129	2 774	642	54	
Saskatchewan	135	2 876	648	53	
Alberta	1 066	13 546	5 675	509	
British Columbia	633	14 321	3 892	390	
Yukon, N.W.T.	5	91	16	1	
TOTAL CANADA	8 886	170 792	41 434	3 481	

* Expressed as SO₂** Expressed as NO₂

TABLE 79 FUEL COMBUSTION EMISSIONS, NATURAL GAS PROCESSING,
1976

Province	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario	18	167	432	26	
Manitoba					
Saskatchewan	6		1 242	8	
Alberta	580	350	127 960	993	
British Columbia	108		1 220	164	
Yukon, N.W.T.	1	52	13	2	
TOTAL CANADA	713	569	130 867	1 193	

* Expressed as SO₂

** Expressed as NO₂

TABLE 80 FUEL COMBUSTION EMISSIONS, CLAY PRODUCTS MANUFACTURE, 1976

Province	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	3	55	6	1	
Prince Edward Island					
Nova Scotia	37	605	69	5	
New Brunswick	14	222	26	2	
Quebec	117	1 899	222	18	2
Ontario	115	1 126	252	23	26
Manitoba			1		
Saskatchewan	1		8		1
Alberta	5		22	2	5
British Columbia	5	27	16	1	3
Yukon, N.W.T.					
TOTAL CANADA	297	3 934	622	52	37

* Expressed as SO₂

** Expressed as NO₂

3.3 Commercial Fuel Combustion

3.3.1 General. Emissions due to the combustion of fuel in commercial establishments are estimated in this section. The same types of fuels used for industrial fuel combustion are considered, with the exception of coal, propane and butane.

3.3.2 Emissions. Fuel consumption figures were obtained from Statistics Canada publications (51, 52, 65). Emission factors were based on a U.S. Environmental Protection Agency publication (1).

Emission factors and total emissions from commercial fuel combustion are presented in Tables 81 and 82 respectively.

TABLE 81 UNCONTROLLED EMISSION FACTORS, COMMERCIAL FUEL COMBUSTION

Source	Emission factors (kg/10 ³ litres)					
	Particulate matter		Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Natural gas ^a	160		9.6	1280	128	320
Light fuel oil ^b	0.25	E. Canada	8.5	2.8	0.12	0.63
		W. Canada	5.1			
Heavy fuel oil ^b						
E. Canada	3.505	E. Canada	47.5	11.25	0.12	0.63
W. Canada	2.88	W. Canada	38.0			
Stove oil and kerosene ^b	0.25	E. Canada	8.5	2.8	0.12	0.63
		W. Canada	5.1			

* Expressed as SO₂

** Expressed as NO₂

a Emission factors expressed as kg/10⁶ m³

b From reference (1) under "Fuel Oil Combustion"

TABLE 82 TOTAL EMISSIONS, COMMERCIAL FUEL COMBUSTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	228	3 782	1 004	23	122
Prince Edward Island	46	780	207	4	26
Nova Scotia	651	9 609	2 397	40	208
New Brunswick	431	6 465	1 631	29	151
Quebec	4 894	74 396	19 772	411	2 021
Ontario	2 053	19 493	15 160	704	2 166
Manitoba	166	1 178	1 442	78	221
Saskatchewan	59	199	643	39	107
Alberta	381	166	4 544	301	759
British Columbia	488	4 700	3 533	162	497
Yukon, N.W.T.	20	387	201	8	43
TOTAL CANADA	9 417	121 155	50 534	1 799	6 321

* Expressed as SO₂

** Expressed as NO₂

3.4 Residential Fuel Combustion

3.4.1 General. In this section fuels consumed mainly for residential heating and air conditioning are considered.

3.4.2 Emissions. Fuel consumption quantities for heavy fuel oil, light fuel oil, coal, natural gas, butane, propane, and stove oil and kerosene were obtained from several Statistics Canada publications (51, 52, 53, 65). Emission factors were taken from a U.S. Environmental Protection Agency publication (1). Ash and sulphur content of fuels used in various provinces were either obtained from the literature (55) or elsewhere (56).

Emission factors and total emissions due to residential fuel combustion are given in Tables 83 and 84 respectively.

TABLE 83 UNCONTROLLED EMISSION FACTORS, RESIDENTIAL FUEL COMBUSTION

Source	Emission factors (kg/10 ³ litres)					
	Particulate matter		Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Natural gas ^a	160		9.6	1920	128	320
Propane ^d	0.22		0.00366	0.80	0.084	0.23
Butane ^d	0.23		0.00366	1.0	0.096	0.24
Light fuel oil ^e	0.31	E. Canada	8.5	2.3	0.12	0.63
		W. Canada	5.1			
Heavy fuel oil ^e						
	E. Canada	E. Canada	47.5	11.25	0.12	0.63
	W. Canada	W. Canada	38.0			
Stove oil and kerosene ^e	0.31	E. Canada	8.5	2.3	0.12	0.63
		W. Canada	5.1			
Coal ^b	10.0		11.4-133.0 ^c	1.5	10.0	45.0

* Expressed as SO₂

** Expressed as NO₂

a Emission factors expressed as kg/10⁶m³

b Emission factors expressed as kg/tonne

c Emission factors vary by province, depending upon the sulphur content of coals used.

d From reference (1) under "Liquefied Petroleum Gas Consumption"

e From reference (1) under "Fuel Oil Combustion"

3.5 Fuelwood Combustion

3.5.1 General. This section includes emissions from the use of wood as a fuel that is burned in small commercial and residential stoves, furnaces and fireplaces.

3.5.2 Emissions. Primary forest fuelwood production for each province in 1976 was taken from the literature (72). Emission factors used (1) were the best available and seem to provide the best estimate. The hydrocarbon emission factor was obtained from an U.S. Environmental Protection Agency publication (103).

TABLE 84 TOTAL EMISSIONS, RESIDENTIAL FUEL COMBUSTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	143	3 929	1 064	56	291
Prince Edward Island	47	1 269	346	18	95
Nova Scotia	781	10 680	2 395	571	2 648
New Brunswick	296	7 210	1 821	134	675
Quebec	3 164	61 957	16 962	728	3 577
Ontario	2 418	27 742	17 029	1 087	4 296
Manitoba	193	1 306	1 442	117	374
Saskatchewan	268	1 820	1 832	166	574
Alberta	1 464	1 836	3 169	1 346	5 518
British Columbia	510	4 814	3 621	259	931
Yukon, N.W.T.	9	110	60	4	17
TOTAL CANADA	9 293	122 673	49 741	4 486	18 996

* Expressed as SO₂

** Expressed as NO₂

Emission factors and total emissions attributable to fuelwood combustion are listed in Tables 85 and 86 respectively.

3.6 Emissions By Fuel Type

3.6.1 General. The major fuels consumed in stationary combustion sources are coal, heavy fuel oil, light fuel oil and natural gas. Emissions from the combustion of these fuels in residential heating, industrial and commercial units and power generating stations, by fuel type, are given in Tables 87 to 90.

TABLE 85 UNCONTROLLED EMISSION FACTORS, FUELWOOD COMBUSTION

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Fuelwood combustion	10.0	Neg.	0.5	35.0	60.0

* Expressed as SO₂** Expressed as NO₂

Neg. - Negligible

TABLE 86 TOTAL EMISSIONS, FUELWOOD COMBUSTION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	972		49	3 402	5 833
Prince Edward Island	384		19	1 343	2 302
Nova Scotia	1 919		96	6 715	11 512
New Brunswick	1 791		90	6 268	10 745
Quebec	16 629		831	58 201	99 772
Ontario	8 314		416	29 100	49 886
Manitoba	1 535		77	5 372	9 210
Saskatchewan	2 047		102	7 163	12 280
Alberta	1 100		55	3 850	6 600
British Columbia	256		13	895	1 535
Yukon, N.W.T.	281		14	985	1 688
TOTAL CANADA	35 228		1 762	123 294	211 363

* Expressed as SO₂** Expressed as NO₂

TABLE 87 TOTAL EMISSIONS, COAL USE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia	16 179	27 184	11 380	559	2 390
New Brunswick	6 518	30 826	2 133	90	326
Quebec	6 131	22 401	3 537	236	472
Ontario	13 504	360 211	73 698	1 363	4 200
Manitoba	6 935	10 139	8 715	267	734
Saskatchewan	38 129	27 268	26 190	581	1 922
Alberta	108 940	33 564	19 052	1 956	7 752
British Columbia	678	743	487	34	74
Yukon, N.W.T.					
TOTAL CANADA	197 014	512 336	145 192	5 086	17 870

* Expressed as SO₂** Expressed as NO₂

TABLE 88 TOTAL EMISSIONS, HEAVY FUEL OIL USE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	2 296	31 226	6 748	78	403
Prince Edward Island	1 021	13 680	3 790	38	200
Nova Scotia	11 010	150 457	34 622	358	1 846
New Brunswick	6 581	104 081	24 827	258	1 348
Quebec	18 764	254 652	59 893	655	3 354
Ontario	10 196	166 350	45 018	521	2 665
Manitoba	457	6 023	1 783	19	100
Saskatchewan	48	640	190	1	10
Alberta	15	203	61		3
British Columbia	3 541	46 775	13 863	148	776
Yukon, N.W.T.	80	1 022	369	4	21
TOTAL CANADA	54 009	775 109	191 164	2 080	10 726

* Expressed as SO₂** Expressed as NO₂

TABLE 89 TOTAL EMISSIONS, LIGHT FUEL OIL USE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	145	4 205	1 254	60	312
Prince Edward Island	44	1 046	359	18	94
Nova Scotia	360	9 749	3 161	127	677
New Brunswick	267	7 234	2 266	102	540
Quebec	1 849	54 076	15 677	763	4 008
Ontario	1 728	29 885	15 290	703	3 698
Manitoba	70	1 180	597	27	145
Saskatchewan	59	1 023	486	24	126
Alberta	37	650	316	15	81
British Columbia	279	4 810	2 288	113	594
Yukon, N.W.T.	27	547	291	13	67
TOTAL CANADA	4 865	114 405	41 985	1 965	10 342

* Expressed as SO₂** Expressed as NO₂

TABLE 90 TOTAL EMISSIONS, NATURAL GAS USE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick			5		1
Quebec	368	22	5 210	186	666
Ontario	2 828	369	53 063	1 549	5 537
Manitoba	276	16	3 405	176	525
Saskatchewan	457	27	9 987	206	772
Alberta	2 225	439	155 580	1 751	2 802
British Columbia	725	36	9 426	517	1 144
Yukon, N.W.T.		52	13	2	
TOTAL CANADA	6 879	961	230 689	4 387	11 447

* Expressed as SO₂** Expressed as NO₂

4 EMISSIONS FROM TRANSPORTATION SOURCES

4.1 Gasoline-Powered Motor Vehicles

4.1.1 General. Gasoline-powered motor vehicles include all vehicles driven on public roads and using gasoline as fuel. These were classified into seven categories: automobiles, taxis, light-duty trucks, heavy-duty trucks, buses, motorcycles and snowmobiles. Air pollutant emissions from motor vehicles come from three principal sources: exhaust, crankcase blow-by, and evaporation from the fuel tank and carburetor.

4.1.2 Emissions. Emissions of nitrogen oxides, hydrocarbons and carbon monoxide were calculated by the Air Pollution Control Directorate for all categories except motorcycles and snowmobiles (57). These calculations were based upon vehicle registration figures, the age distribution of Canadian vehicles, estimated speed distribution, emission rate degradation factors and estimated vehicle kilometres travelled per year. For particulates and sulphur oxides, emissions were based upon registrations and emission factors obtained from the literature (1), because more detailed studies have not as yet been undertaken by the Directorate for these two contaminants. The emission factors in terms of grams per kilometre were converted to kilograms per vehicle per year on the assumption that automobiles travel 15 680 km per year, taxis 112 000 km per year, light-duty trucks 19 200 km per year, heavy-duty trucks 24 000 km per year and buses 88 000 km per year. Registration figures from a Statistics Canada publication were used as base quantities (58).

Emission factors and total emissions for gasoline-powered motor vehicles are given in Tables 91 and 92 respectively.

4.2 Railroads

4.2.1 General. Emissions from railroads are based on the quantities of fuels consumed. The fuels included are diesel oil, heavy fuel oil, light fuel oil, stove oil, kerosene and coal.

4.2.2 Emissions. Railroad fuel consumption quantities were obtained from various Statistics Canada publications (59, 52, 51). Emission factors for the combustion of these fuels were based on data from the U.S. Environmental Protection Agency (1). Sulphur contents of fuels (included in the emission factors) were found in an Energy, Mines and Resources publication (55), with the exception of coal for which sulphur and ash content were obtained from an internal government source (56). The only province in which coal

TABLE 91 EMISSION FACTORS, GASOLINE-POWERED MOTOR VEHICLES

Vehicle Type	Emission factors (kg/vehicle/yr)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Automobiles	2.98	1.25			
Taxis	21.28	8.96			
Light-duty trucks	3.65	2.11			
Heavy-duty trucks and Buses	13.44	5.28			
Motorcycles ^a	640.0	115.0	768.0	34 112.0	121 600.0
Snowmobiles ^a	1 670.0	51.0	600.0	37 800.0	58 700.0

* Expressed as SO₂** Expressed as NO₂

a Units are g/unit/yr

TABLE 92 TOTAL EMISSIONS, GASOLINE-POWERED MOTOR VEHICLES, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	759	316	8 205	14 277	116 208
Prince Edward Island	250	108	2 733	4 706	38 659
Nova Scotia	1 463	619	16 029	27 682	226 780
New Brunswick	1 229	512	13 296	23 335	188 863
Quebec	10 255	4 190	110 913	198 911	1 591 150
Ontario	15 488	6 497	170 494	294 509	2 414 302
Manitoba	2 372	995	25 624	44 730	362 416
Saskatchewan	3 202	1 378	34 708	59 266	488 076
Alberta	5 144	2 211	56 535	96 151	796 529
British Columbia	5 977	2 582	66 617	111 918	936 495
Yukon	74	31	804	1 373	11 290
N.W.T.	68	30	733	1 264	10 338
TOTAL CANADA	46 281	19 469	506 691	878 122	7 181 106

* Expressed as SO₂** Expressed as NO₂

was consumed by railroads was Manitoba. An emission control level of 50% was assumed on particulates, emitted from coal combustion.

Emission factors and total emissions for railroads are presented in Tables 93 and 94 respectively.

TABLE 93 EMISSION FACTORS, RAILROADS

Source	Emission factors (kg/10 ³ litres)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Diesel oil ^a	3.0	6.8	44.0	11.0	16.0
Heavy fuel oil ^b	2.75	E. Canada 47.5 W. Canada 38.0	7.2	0.35	0.5
Kerosene, stove and light fuel oil ^c	1.8	E. Canada 8.5 W. Canada 5.1	7.2	0.35	0.5
Coal ^{de}	50.75	9.0	3.0	0.5	1.0

* Expressed as SO₂

** Expressed as NO₂

a Reference (1) under "Average Locomotive Factors"

b Reference (1) under "Fuel Oil Combustion (industrial and commercial residual fuel oil)"

c Reference (1) under "Fuel Oil Combustion (distillate fuel oil)"

d Reference (1) under "Lignite Coal Combustion"

e Emission factors expressed as kg/tonne coal burned

4.3 Marine

4.3.1 General. This sector was broken down into four main sections: steam and motor ships which use heavy fuel oil and diesel oil respectively, gasoline-powered outboard motors, light fuel oil consumption and kerosene or stove oil consumption.

4.3.2 Emissions. A ship may create emissions both within and outside Canada. These data are not available. While in port, a ship continues to run its engines or boilers to generate power, and is a source of pollution. The number of calls in port, for steam and motor ships, was estimated from the number of ships at Canadian ports for coastwise

TABLE 94 TOTAL EMISSIONS, RAILROADS (ALL FUELS), 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	95	501	1 113	263	383
Prince Edward Island	73	228	1 008	250	362
Nova Scotia	129	462	1 744	426	622
New Brunswick	338	1 347	4 434	1 084	1 577
Quebec	1 284	6 404	15 825	3 816	5 552
Ontario	2 282	5 687	32 457	8 053	11 715
Manitoba	2 228	2 244	10 580	2 620	3 826
Saskatchewan	395	1 013	5 572	1 381	2 008
Alberta	471	1 095	6 791	1 689	2 456
British Columbia	1 044	2 997	14 567	3 607	5 246
Yukon, N.W.T.	11	29	143	33	48
TOTAL CANADA	8 350	22 007	94 234	23 222	33 795

* Expressed as SO₂

** Expressed as NO₂

and international shipping (62, 63). The average time that a ship remained in port (per call) was 2.66 days (64).

Sales figures for stove oil, kerosene and light fuel oil for marine applications were obtained from the literature (52). Statistics for the number of outboard-powered boats was also obtained from the literature (104). An average of 9.1 hp and an average usage of 50 hours per year were assumed (57). Particulate emissions are assumed to be negligible since outboards have underwater exhausts.

Average emission factors for the combustion of fuels used by marine sources and the sulphur content (included in the emission factors) of these fuels were found in the literature (1, 55).

Emission factors and total emissions for marine sources are shown in Tables 95 and 96 respectively.

TABLE 95 EMISSION FACTORS, MARINE

Source	Emission factors (kg/call in port)					
	Particulate matter		Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Diesel and heavy fuel oil ^a :						
- steam ships	18.1	E. Canada	917.0	241.3	10.9	0.10
		W. Canada	733.6			
- motor ships	19.9	E. Canada	51.9	60.3	39.8	55.5
		W. Canada	51.9			
Kerosene, stove and light fuel oil ^{bc}	1.8	E. Canada	8.5	7.2	0.35	0.5
		W. Canada	5.1			
Gasoline:						
- outboard motors ^d			0.49	0.50	85.0	250.0

* Expressed as SO₂** Expressed as NO₂

a Reference (1) under "Inboard-Powered Vessels"

b Reference (1) under "Fuel Oil Combustion (distillate fuel oil)"

c Emission factors expressed as kg/m³

d Units are g/hp/h

4.4 Aircraft

4.4.1 General. Aircraft engines are of two major types: reciprocating (piston) and gas turbine. Both types are further divided into subclasses depending on the size of the aircraft and the most commonly used engine for that class. The types of aircraft included in this section are jets, turboprops, piston-engined planes, helicopters and piston-engined planes at local airports.

4.4.2 Emissions. A study was undertaken to produce weighted averages of U.S. Environmental Protection Agency emission factors (1) for jets, turboprops, piston-engined planes and helicopters. Among the factors considered were the number of each type of

TABLE 96 TOTAL EMISSIONS, MARINE (ALL FUELS), 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	207	603	647	1 180	2 840
Prince Edward Island	4	15	14	86	240
Nova Scotia	82	571	335	680	1 782
New Brunswick	45	194	154	552	1 487
Quebec	200	1 899	919	3 142	8 663
Ontario	172	2 313	1 079	9 998	28 978
Manitoba	2	11	12	1 200	3 528
Saskatchewan		7	7	1 160	3 413
Alberta		8	9	1 470	4 323
British Columbia	335	1 045	1 097	3 991	10 764
Yukon, N.W.T.	1	3	4	3	4
TOTAL CANADA	1 048	6 669	4 277	23 462	66 022

* Expressed as SO₂

** Expressed as NO₂

aircraft registered in Canada, the size distribution of planes within each type and the average number of engines per plane for each type. This information was available from an internal source (57).

The estimates for all contaminants are presented for emissions occurring below an altitude of 1100 metres and are based upon the number of 'landing-and-takeoff cycles' (one descent and landing from 1100 metres, ground movements, and one takeoff and climb-out to 1100 metres) made by the various aircraft types. Statistics on Canadian aircraft movements were obtained from the literature (61).

Emission factors and total emissions attributable to aircraft operations are given in Tables 97 and 98 respectively.

4.5 Off-Road Use of Gasoline

4.5.1 General. Off-road gasoline use was mainly for construction equipment, agricultural equipment and forestry equipment. Approximately 8.5% of the gasoline sold in Canada was not consumed on public roads and highways.

TABLE 97 EMISSION FACTORS, AIRCRAFT

Source	Emission factors (kg/aircraft/LTO cycle)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Jets	0.621	1.061	11.29	11.34	22.60
Turboprops	0.481	0.191	1.32	1.093	2.994
Piston-engined planes	0.024	0.029	0.032	1.152	8.464
Helicopters	0.113	0.163	0.259	0.236	2.585
Local ^a	0.011	0.016	0.023	0.023	6.917

* Expressed as SO₂** Expressed as NO₂

a Reference (1) under "General Aviation Piston Planes"

TABLE 98 TOTAL EMISSIONS, AIRCRAFT, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	15	24	221	244	736
Prince Edward Island	2	2	18	25	144
Nova Scotia	12	18	185	203	631
New Brunswick	14	20	151	240	1 853
Quebec	90	127	1 179	1 434	6 407
Ontario	121	171	1 539	2 048	11 850
Manitoba	28	36	337	428	1 840
Saskatchewan	14	18	158	244	1 549
Alberta	55	73	653	901	4 811
British Columbia	67	94	811	1 216	6 951
Yukon	4	4	28	48	394
N.W.T.	16	13	102	139	645
TOTAL CANADA	438	600	5 382	7 170	37 811

* Expressed as SO₂** Expressed as NO₂

4.5.2 Emissions. Gasoline consumption figures were obtained from the literature (52, 77). Emission factors were taken from the U.S. Environmental Protection Agency (1), and are listed in Table 99. Total emissions attributable to the off-road use of gasoline are listed in Table 100.

TABLE 99 EMISSION FACTORS, OFF-ROAD USE OF GASOLINE

Source	Emission factors (kg/10 ³ litres)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Agricultural equipment	0.892	0.636	14.95	16.80	441.5
Heavy-duty construction	0.855	0.632	13.54	28.07	445.6
Industrial engines	0.775	0.636	12.2	27.43	472.0
Average	0.841	0.635	13.56	24.10	453.0

* Expressed as SO₂

** Expressed as NO₂

4.6 Diesel-Powered Engines

4.6.1 General. In this section, emissions resulting from the combustion of diesel fuel are estimated. It is assumed that all diesel oil is used in internal combustion engines, with none being burned industrially or for heating purposes in the manner that heavy or light fuel oils are (except small quantities of diesel oil used in power generation).

The use of diesel oil for power generation, railway and marine applications is dealt with in Sections 3-1, 4-2 and 4-3.

4.6.2 Emissions. Consumption of diesel oil was taken from published data (52). The quantity of diesel oil used in power generation (50) was subtracted from the total figure. Emissions from buses using diesel oil were also considered in this sector based on information from the Air Pollution Control Directorate (57). The emission factors in terms of grams per kilometre were converted to kilograms per vehicle per year on the assumption that buses travel 88 000 km per year. Registration figures from Statistics Canada were used as base quantities (58).

TABLE 100 TOTAL EMISSIONS, OFF-ROAD USE OF GASOLINE, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	23	17	367	650	12 232
Prince Edward Island	12	9	195	345	6 495
Nova Scotia	52	39	831	1 472	27 705
New Brunswick	45	34	733	1 298	24 439
Quebec	100	75	1 605	2 844	53 521
Ontario	616	464	9 943	17 618	331 611
Manitoba	181	137	2 926	5 185	97 585
Saskatchewan	590	445	9 518	16 866	317 447
Alberta	596	450	9 628	17 062	321 132
British Columbia	152	115	2 461	4 361	82 078
Yukon	4	3	63	111	2 084
N.W.T.	3	2	47	84	1 580
TOTAL CANADA	2 374	1 790	38 317	67 896	1 277 909

* Expressed as SO₂

** Expressed as NO₂

Emission factors and total emissions for diesel-powered engines are presented in Tables 101 and 102 respectively.

4.7 Tire Wear

4.7.1 General. Emissions from tire wear are generated by all vehicles equipped with rubber tires. The abrasive action of the gravel or asphalt roads on the tires removes minute particles from the surface of the tire in contact with the road. The friction between a tire and the surface of a road, especially in some driving conditions, creates sufficient heat to generate traces of hydrocarbon gases.

4.7.2 Emissions. A recent study (113) has revealed that 5% of the total tread wear consisted of airborne particulate matter and 1% hydrocarbon gases. A study done at the University of Cincinnati indicated that the average tire life is 32 000 km and the corresponding loss in weight is about 2.09 kg (114). All highway vehicle types have been

TABLE 101 EMISSION FACTORS, DIESEL-POWERED ENGINES

Source	Emission factors (kg/10 ³ litres)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Heavy-duty vehicles ^a	1.56	3.23	44.3	4.43	26.9
Buses ^b	71.28	149.6	1 870.0	187.4	1 122.0

* Expressed as SO₂** Expressed as NO₂

a Reference (1) under "Heavy-Duty, Diesel-Powered Vehicles"

b Units are kg/vehicle/yr.

TABLE 102 TOTAL EMISSIONS, DIESEL-POWERED ENGINES, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	277	573	7 811	781	4 740
Prince Edward Island	46	96	1 309	131	794
Nova Scotia	488	1 009	13 809	1 381	8 382
New Brunswick	382	792	10 837	1 084	6 579
Quebec	2 713	5 633	75 964	7 596	46 032
Ontario	3 158	6 563	87 749	8 775	53 114
Manitoba	615	1 274	17 413	1 741	10 569
Saskatchewan	1 215	2 516	34 408	3 441	20 886
Alberta	1 917	3 973	54 141	5 414	32 851
British Columbia	2 020	4 181	56 737	5 674	34 407
Yukon	162	335	4 584	458	2 784
N.W.T.	151	313	4 273	427	2 593
TOTAL CANADA	13 144	27 258	369 035	36 903	223 731

* Expressed as SO₂** Expressed as NO₂

included and the provincial registration figures were taken from a Statistics Canada publication (58). An assumption was made as to the distance travelled per year per vehicle type as illustrated in Section 4.1.

Emission factors and total emissions are summarized in Tables 103 and 104 respectively.

TABLE 103 EMISSION FACTORS, TIRE WEAR

Source	Emission factors (mg/km/tire)	
	Particulate matter	Hydro-carbons
Tire wear	3.27	0.65

TABLE 104 TOTAL EMISSIONS, TIRE WEAR, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	39			8	
Prince Edward Island	13			3	
Nova Scotia	79			16	
New Brunswick	65			13	
Quebec	590			118	
Ontario	894			179	
Manitoba	126			25	
Saskatchewan	152			30	
Alberta	266			53	
British Columbia	322			64	
Yukon	3			1	
N.W.T.	3			1	
TOTAL CANADA	2 552			511	

* Expressed as SO₂

** Expressed as NO₂

5 SOLID WASTE INCINERATION

Solid waste is defined as discarded solid materials, including those resulting from industrial, commercial, agricultural and community activities. Atmospheric emissions, both gaseous and particulate, result from refuse disposal operations that use combustion.

The sources considered in this section are municipal incineration, sewage sludge incineration, industrial and commercial incineration, and wigwam burners.

5.1 Municipal Incineration

5.1.1 Process Description. Municipal incinerators normally have capacities in excess of 50 tonnes per day and are usually equipped with automatic charging mechanisms and temperature controls. The most common type of municipal incinerator consists of a refractory-lined chamber with a grate upon which refuse is burned. It is usually batch-fed. In some newer incinerators, water-walled furnaces are used.

In 1976, approximately 1.19 million tonnes of refuse were disposed of in 17 municipal incinerators. Twelve pit incinerators were also in operation for disposal of municipal refuse, with a throughput of about 75 000 tonnes of refuse.

5.1.2 Emission Sources. Large quantities of uncombusted particulates and carbon monoxide are emitted after charging of batch-fed units. In continuously-fed units, furnace particulate emissions depend mainly upon the type of grate used.

5.1.3 Controls. Pit incinerators were largely uncontrolled and particulate control on other municipal incinerators varied widely. Water sprays, with an average control efficiency of 45%, settling chambers or, in newer plants, electrostatic precipitators were the most common types of air pollution control equipment used.

5.1.4 Emissions. Information on control equipment and quantities of municipal refuse burned in different incinerators across Canada, was obtained from several sources (7, 46, 47, 36). Emission factors were taken from a U.S. Environmental Protection Agency publication (1) for all contaminants, except for particulates where questionnaire information was available (7). Pit incinerator information was available from the same sources (1, 7, 46, 47).

Emission factors and total emissions for municipal incineration are presented in Tables 105 and 106 respectively.

TABLE 105 UNCONTROLLED EMISSION FACTORS, MUNICIPAL INCINERATION

Source	Emission factors (kg/tonne charged material)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Municipal incinerators	15.0	1.25	1.50	0.75	17.50
Pit incinerators					
- open pit	4.98	1.25	0.13	0.11	8.57
- closed pit	6.20	1.25	0.13	0.11	8.57

* Expressed as SO₂** Expressed as NO₂

TABLE 106 TOTAL EMISSIONS, MUNICIPAL INCINERATION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia	744	146	176	88	2 058
New Brunswick					
Quebec	2 681	751	860	430	10 265
Ontario	2 664	514	589	295	7 038
Manitoba	1 687	120	142	71	1 669
Saskatchewan	124	21	18	9	251
Alberta					
British Columbia	65	15	4	3	129
Yukon, N.W.T.					
TOTAL CANADA	7 965	1 567	1 789	896	21 410

* Expressed as SO₂** Expressed as NO₂

5.2 Industrial and Commercial Incineration

5.2.1 Process Description. Industrial and commercial incinerators are generally capable of burning from 25 to 1800 kg of refuse per hour. Of these intermediate-size units the most common are of multiple chamber design. Gases from the primary chamber flow to a small secondary mixing chamber where more air is admitted and therefore more complete oxidation occurs.

Controlled air incinerators operate on a controlled combustion principle where refuse is burned in the absence of sufficient oxygen to complete combustion in the main chamber. This process generates a highly combustible gas mixture that is then burned with excess air in a secondary chamber, resulting in efficient combustion.

In 1976, approximately 685 000 tonnes of refuse were burned in industrial and commercial incinerators.

5.2.2 Emission Sources. Carbon monoxide and particulate matter are the major contaminants emitted from incineration of refuse in industrial or commercial incinerators. Emissions of the other contaminants also occur depending upon the type of incinerator being used.

5.2.3 Controls. Most of the industrial and commercial incinerators were without control; however, multiple chamber units usually had afterburners installed as part of the process to improve combustion.

5.2.4 Emissions. The amount of solid waste incinerated in industrial and commercial units was estimated using information from the literature (78). Emission factors were obtained from an Environment Canada publication (94). Emission factors for multiple chamber incinerators were applied to 75% of the total refuse burned, since 25% of the incinerators used were considered to be the controlled-air type.

Emission factors and total emissions are listed in Tables 107 and 108 respectively.

5.3 Sewage Sludge Incineration

5.3.1 Process Description. Sewage sludge is a by-product of sewage treatment processes. Although a number of alternatives exist for the treatment and disposal of sludge, incineration was the disposal method used in six municipalities in Canada, in 1976. Approximately 71 000 tonnes of sewage sludge were incinerated.

In the incineration process, sludge is freed of moisture prior to combustion and elevated to the ignition point. Air and auxiliary fuel may be required to support and

TABLE 107 UNCONTROLLED EMISSION FACTORS, INDUSTRIAL AND COMMERCIAL INCINERATION

Incinerator type	Emission factors (kg/tonne charged material)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Multiple chamber	2.2	1.25	1.1	0.5	1.8
Controlled air	0.9	0.75	1.6	Neg.	Neg.

* Expressed as SO_2

** Expressed as NO_2

Neg. - negligible

TABLE 108 TOTAL EMISSIONS, INDUSTRIAL AND COMMERCIAL INCINERATION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	21	13	14	4	15
Prince Edward Island	6	3	4	1	4
Nova Scotia	43	26	28	9	31
New Brunswick	33	20	22	7	24
Quebec	332	199	217	66	239
Ontario	517	311	338	104	373
Manitoba	56	34	37	11	41
Saskatchewan	42	25	27	8	30
Alberta	94	57	62	19	68
British Columbia	137	82	90	28	99
Yukon, N.W.T.	3	2	2	1	2
TOTAL CANADA	1 284	772	841	258	926

* Expressed as SO_2

** Expressed as NO_2

maintain combustion. The residual inorganic ash is then cooled and disposed of. Multiple-hearth furnaces were used at three incineration facilities, while the other three facilities employed the fluidized-bed type.

5.3.2 Emission Sources. A major particulate emission source is the furnace itself. Odour can be a problem in multiple-hearth systems as unburned volatiles are given off in the upper drying hearth. Sulphur oxides and nitrogen oxides are also emitted in significant amounts, with hydrocarbons also being emitted in small quantities.

5.3.3 Emissions. Information on the quantities of sludge incinerated and on controls was obtained from various sources (7, 47). Uncontrolled emission factors for multiple hearth furnaces were calculated from actual source testing data at one plant and applied to the others.

Emission factors for fluidized-bed units were obtained from the U.S. Environmental Protection Agency (1). These factors were used where actual emission data were not available. Emission factors and total emissions for sewage sludge incineration are presented in Tables 109 and 110 respectively.

TABLE 109 UNCONTROLLED EMISSION FACTORS, SEWAGE SLUDGE INCINERATION

Incinerator type	Emission factors (kg/tonne dry sludge)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Multiple-hearth furnace	11.5	10	3	0.75	Neg.
Fluidized-bed	50	0.5	3	0.75	Neg.

* Expressed as SO_2

** Expressed as NO_2

Neg. - negligible

5.4 Wigwam Burners

5.4.1 General. The wigwam burner, used for disposal of sawdust, is a major source of air pollution associated with the lumber and plywood industry.

5.4.2 Emissions. An estimate of the amount of waste wood burned, based on production of softwood and hardwood lumber, was used to calculate an estimate of wood waste relative to production (46, 79, 95). Emissions were calculated using emission factors from the U.S. Environmental Protection Agency (1).

TABLE 110 TOTAL EMISSIONS, SEWAGE SLUDGE INCINERATION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island					
Nova Scotia					
New Brunswick					
Quebec					
Ontario	146	677	203	51	Neg.
Manitoba					
Saskatchewan	4	1	5	1	Neg.
Alberta					
British Columbia	17	3	4	1	Neg.
Yukon, N.W.T.					
TOTAL CANADA	167	681	212	53	Neg.

* Expressed as SO₂** Expressed as NO₂

Neg. - negligible

Emission factors and total emissions for solid waste disposal by wigwam burners are given in Tables 111 and 112 respectively.

TABLE 111 UNCONTROLLED EMISSION FACTORS, WIGWAM BURNERS

Source	Emission factors (kg/tonne)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Wigwam burners	5.5	0.05	0.5	5.5	65.0

* Expressed as SO₂** Expressed as NO₂

TABLE 112 TOTAL EMISSIONS, WIGWAM BURNERS, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	68	1	6	68	808
Prince Edward Island	19		2	19	225
Nova Scotia	298	3	27	298	3 519
New Brunswick	517	5	47	517	6 113
Quebec	3 854	35	350	3 854	45 543
Ontario	1 865	17	170	1 865	22 039
Manitoba	153	1	14	153	1 809
Saskatchewan	310	3	28	310	3 659
Alberta	808	7	74	808	9 548
British Columbia	16 860	153	1 533	16 860	199 256
Yukon, N.W.T.	7		1	7	86
TOTAL CANADA	24 759	225	2 252	24 759	292 605

* Expressed as SO₂** Expressed as NO₂

6 EMISSIONS FROM MISCELLANEOUS SOURCES

6.1 Fertilizer Application

6.1.1 Process Description. The use of fertilizer involves both handling the product, in bags or bulk, and spreading it in the field.

6.1.2 Emission Sources. The main emission source is the spreading operation; many fine particulates including those produced by abrasion enter the atmosphere during this operation. The activity of spreading is more vigorous than that of bulk material handling encountered in the fertilizer manufacturing industry.

6.1.3 Controls. A control efficiency of 50% was assumed on handling operations. Spreading, because of the nature of the operation, was considered to be uncontrolled.

6.1.4 Emissions. About 90% of the total particulate emissions from fertilizer application in Canada was due to field application of fertilizer. Consumption of fertilizer for agricultural application in Canada in 1976, emission factors, and control levels for each operation were obtained from the literature (35, 90).

Emission factors and total emissions for fertilizer application are presented in Tables 113 and 114 respectively.

TABLE 113 UNCONTROLLED EMISSION FACTORS, FERTILIZER APPLICATION

Operation	Emission factors (kg/tonne fertilizer)
	Particulate Matter
Bulk handling, loading	0.5
Spreading	2.0

6.2 Pesticide Manufacturing and Application

6.2.1 General. Most of the pesticides imported into Canada are technical grade pesticides which are subsequently formulated for direct application. Formulated products can be in solid form with varying particle sizes, in liquid or gaseous form. The methods of application are numerous, from hand-held sprays to aerial spraying.

TABLE 114 TOTAL EMISSIONS, FERTILIZER APPLICATION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	11				
Prince Edward Island	118				
Nova Scotia	73				
New Brunswick	128				
Quebec	866				
Ontario	2 138				
Manitoba	831				
Saskatchewan	640				
Alberta	1 298				
British Columbia	152				
Yukon, N.W.T.					
TOTAL CANADA	6 255				

* Expressed as SO₂

** Expressed as NO₂

6.2.2 Emissions. There are four main sources of emissions: Manufacturing, Formulation, Application, and Post-Application. Good emission controls are used at manufacturing and formulating plants; however, no control is available for the latter two sources. Emissions from these sources vary considerably and are dependent on the physical and chemical characteristics of the pesticide, on the method of application as well as on meteorological conditions.

Particulate emission factors were obtained from published literature (115, 116). The quantity of technical grade pesticide was taken from a Statistics Canada publication (117), while the amount of pesticide in formulated products was provided by Agriculture Canada (118).

Tables 115 and 116 summarize the emission factors and total emissions for pesticide manufacturing and application respectively.

TABLE 115 EMISSION FACTORS, PESTICIDE MANUFACTURING AND APPLICATION

Source	Emission factors (kg/tonne of pesticide)
	Particulate Matter
Manufacturing	1.0 ^a
Formulation	1.0 ^a
Application	8.9 ^b
Post Application	13.4 ^b

a Controlled emission factor

b Uncontrolled emission factor

TABLE 116 TOTAL EMISSIONS, PESTICIDE MANUFACTURING AND APPLICATION, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland					
Prince Edward Island	22				
Nova Scotia	8				
New Brunswick	17				
Quebec	70				
Ontario	424				
Manitoba	572				
Saskatchewan	1 091				
Alberta	745				
British Columbia	27				
Yukon, N.W.T.					
TOTAL CANADA	2 976				

* Expressed as SO₂** Expressed as NO₂

6.3 Gasoline and Diesel Marketing

6.3.1 Process Description. The handling of gasoline and diesel fuels from the refinery to the consumer results in the loss of hydrocarbons to the atmosphere by evaporation.

6.3.2 Emission Sources. Emissions from gasoline-marketing facilities involve the losses caused by product transfer activities (loading-unloading) and the losses associated with storage tanks located at terminal sites (excluding storage within refineries).

Hydrocarbons are the only contaminants considered for these sources.

6.3.3 Emissions. Emission factors were obtained from the Air Pollution Control Directorate (71) and a U.S. Environmental Protection Agency document (1). It was assumed that all gasoline passes through tank trucks at one time or another and that each province transported only a percentage of total distribution by ship or barge. Emission factors for diesel marketing were assumed to be 10% of those for gasoline.

Emission factors and total emissions are presented in Tables 117 and 118 respectively.

6.4 Dry Cleaning

6.4.1 Process Description. Textiles may be cleaned by treating them either with chlorinated synthetic solvents or petroleum solvents.

Dry cleaning operations involve agitating the clothing in a solvent bath, rinsing with clean solvent and drying with warm air.

6.4.2 Emission Sources. Hydrocarbons are the only contaminants considered in these operations and result from the evaporation of organic solvents.

6.4.3 Emissions. In the absence of information on the quantities of solvents consumed for dry cleaning purposes in each province, emissions were based on population. A controlled emission factor of 1.225 kg of hydrocarbons per capita per year was used (1). The control level was estimated to be minimal.

Total emissions from dry cleaning are presented in Table 119.

6.5 Application of Surface Coatings

6.5.1 Process Description. Surface-coating operations primarily involve the application of paint, lacquer, varnish or paint primer for decorative or protective purposes. The major Canadian surface coating applicators include the automobile, strip, sheet and coil coating and household appliance manufacturing industries.

TABLE 117 UNCONTROLLED EMISSION FACTORS, GASOLINE AND DIESEL MARKETING

Source	Emission factors (kg/10 ³ litres)
	Hydrocarbons
LOADING AND UNLOADING ACTIVITIES	
Losses from refinery storage to tankcar/truck (90% submerged loading)	
- Submerged	0.44
- Splash	1.44
- Marine	0.325
- Transit	0.18
- Unloading	0.25
TANKCAR/TRUCK TO GAS STATION, UNDERGROUND STORAGE.	
- Submerged loading	0.876
- Unloading	0.125
- Filling motor vehicle gasoline tank	1.375
- Spillage at gasoline station	0.084
VAPOUR LOSSES FROM STORAGE TANKS AT TERMINAL SITES (excluding refineries)	
	3.30

6.5.2 Emission Sources. Hydrocarbons are the only contaminants considered for this operation and emissions arise from the evaporation of solvents as the coating dries.

6.5.3 Emissions. Solvent consumption (including imports less exports) was obtained from the literature (80). It was assumed that all solvents are lost or emitted. An internal report (28) reported national emissions for both trade and industrial sales. Emissions were calculated on a provincial basis based on population for trade sales (73) and on industrial labour force for industrial sales (74).

Total emissions for application of surface coatings are presented in Table 120.

TABLE 118 TOTAL EMISSIONS, GASOLINE AND DIESEL MARKETING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland				3 774	
Prince Edward Island				1 143	
Nova Scotia				7 518	
New Brunswick				6 578	
Quebec				53 725	
Ontario				77 818	
Manitoba				8 715	
Saskatchewan				9 068	
Alberta				20 385	
British Columbia				22 329	
Yukon				323	
N.W.T.				244	
TOTAL CANADA				211 620	

* Expressed as SO₂

** Expressed as NO₂

6.6 Forest Fires

6.6.1 General. Approximately 18 100 square kilometres of forest in Canada were consumed by fire in 1976.

6.6.2 Emission Sources. Forest fires are a major natural source of air contaminants and produce large quantities of carbon monoxide, hydrocarbons and particulate matter. Nitrogen oxides are also emitted, but at lower rates.

6.6.3 Emissions. Information on the number of acres burned in each province was obtained from internal sources (81). This was converted to tonnes of dry wood using a conversion factor of 3811 tonnes/km² (82).

Emission factors and total emissions for forest fires are given in Tables 121 and 122 respectively.

TABLE 119 TOTAL EMISSIONS, DRY CLEANING INDUSTRY, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland				686	
Prince Edward Island				146	
Nova Scotia				1 021	
New Brunswick				834	
Quebec				7 660	
Ontario				10 172	
Manitoba				1 254	
Saskatchewan				1 137	
Alberta				2 281	
British Columbia				3 035	
Yukon				27	
N.W.T.				53	
TOTAL CANADA				28 306	

* Expressed as SO₂

** Expressed as NO₂

6.7 Structural Fires

6.7.1 General. Canada had approximately 70 000 structural fires in 1976.

6.7.2 Emission Sources. Significant amounts of carbon monoxide, particulate matter and hydrocarbons are emitted from building fires. Emissions of nitrogen oxides are considered negligible.

6.7.3 Emissions. Information on the number of fires in each province was obtained from a government publication (83). Emission factors used were those from a previous inventory based on one million fires (3).

Emission factors and total emissions attributable to structural fires in Canada are presented in Tables 123 to 124 respectively.

TABLE 120 TOTAL EMISSIONS, APPLICATION OF SURFACE COATINGS, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland				2 516	
Prince Edward Island				551	
Nova Scotia				3 851	
New Brunswick				3 127	
Quebec				37 414	
Ontario				59 860	
Manitoba				4 864	
Saskatchewan				4 369	
Alberta				8 623	
British Columbia				15 620	
Yukon, N.W.T.				296	
TOTAL CANADA				141 091	

* Expressed as SO₂

** Expressed as NO₂

6.8 Slash Burning

6.8.1 General. Slash is burned to reduce the hazard of forest fires, for insect control, and for the provision of favourable growing conditions for seedlings.

6.8.2 Emission Sources. Slash burning is a major source of air pollution associated with the logging industry. In comparison to refuse incineration, the emission of particulates, carbon monoxide, and hydrocarbons in slash burning is greater because of the relatively low temperatures associated with this operation. Likewise, nitrogen oxide emissions are suppressed. Sulphur oxide emissions are a direct function of the sulphur content of the refuse burned and are considered negligible.

6.8.3 Emissions. Information on the quantity of slash burned in Canada in 1976 was not available. A study was carried out using limited information from the literature (84, 85, 72). Emission factors were obtained from a U.S. Environmental Protection Agency publication (1).

TABLE 121 UNCONTROLLED EMISSION FACTORS, FOREST FIRES

Source	Emission factors (kg/tonne)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Forest fires	8.5	Neg.	2.0	12.0	70.0

* Expressed as SO₂** Expressed as NO₂

Neg.- negligible

TABLE 122 TOTAL EMISSIONS, FOREST FIRES, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	63 639		14 974	89 843	524 084
Prince Edward Island	38		9	54	312
Nova Scotia	5 680		1 336	8 020	46 778
New Brunswick	1 495		352	2 111	12 314
Quebec	18 446		4 340	26 042	151 908
Ontario	176 251		41 471	248 824	1 451 475
Manitoba	41 494		9 763	58 580	341 712
Saskatchewan	29 473		6 935	41 608	242 713
Alberta	7 276		1 712	10 271	59 915
British Columbia	18 447		4 340	26 043	151 914
Yukon	17 105		4 024	24 148	140 864
N.W.T.	207 902		48 918	293 508	1 712 133
TOTAL CANADA	587 246		138 174	829 052	4 836 122

* Expressed as SO₂** Expressed as NO₂

TABLE 123 UNCONTROLLED EMISSION FACTORS, STRUCTURAL FIRES

Source	Emission factors (tonnes/fire)		
	Particulate matter	Hydro-carbons	Carbon monoxide
Structural fires	0.09	0.09	0.18

TABLE 124 TOTAL EMISSIONS, STRUCTURAL FIRES, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	42			42	84
Prince Edward Island	53			53	106
Nova Scotia	191			191	383
New Brunswick	109			109	217
Quebec	1 497			1 497	2 993
Ontario	2 089			2 089	4 178
Manitoba	650			650	1 301
Saskatchewan	260			260	521
Alberta	691			691	1 382
British Columbia	660			660	1 320
Yukon	10			10	20
N.W.T.	17			17	33
TOTAL CANADA	6 269			6 269	12 538

* Expressed as SO₂** Expressed as NO₂

Emission factors and total emissions from slash burning are listed in Tables 125 and 126 respectively.

TABLE 125 UNCONTROLLED EMISSION FACTORS, SLASH BURNING

Source	Emission factors (kg/tonne)			
	Particulate matter	Nitrogen oxides*	Hydro-carbons	Carbon monoxide
Slash burning ^a	8.5	1.0	2.0	25.0

* Expressed as NO₂

a Reference (1) under "Open Burning - Wood Waste"

TABLE 126 TOTAL EMISSIONS, SLASH BURNING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	1 256		148	295	3 693
Prince Edward Island	89		11	21	263
Nova Scotia	1 852		218	436	5 447
New Brunswick	4 010		472	943	11 793
Quebec	15 576		1 832	3 665	45 812
Ontario	9 580		1 127	2 254	28 178
Manitoba	935		110	220	2 751
Saskatchewan	1 539		181	361	4 515
Alberta	3 015		355	709	8 866
British Columbia	37 263		4 384	8 768	109 598
Yukon, N.W.T.	67		8	16	197
TOTAL CANADA	75 182		8 846	17 688	221 113

* Expressed as SO₂

** Expressed as NO₂

6.9 Cigarette Smoking

6.9.1 General. Cigarette smoking is the burning of tobacco at low temperatures. Significant amounts of carbon monoxide are generated since the combustion parameters are uncontrolled. Emissions from a cigarette are relatively very low and are measured in milligrams; however the consumption is high.

6.9.2 Emissions. Particulates and carbon monoxide are emitted. Emission factors for cigarette smoking were taken from a published document prepared by the U.S. Department of Health, Education and Welfare (119). Cigarette consumption was obtained from a Statistics Canada publication (120) and prorated based on population to obtain provincial figures.

Emission factors and total emissions for cigarette smoking are presented in Tables 127 and 128 respectively.

TABLE 127 EMISSION FACTORS, CIGARETTE SMOKING

Source	Emission factors (mg/cigarette)	
	Particulate matter	Carbon Monoxide
Cigarette Smoking	70	28

TABLE 128 TOTAL EMISSIONS, CIGARETTE SMOKING, 1976

	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	105				42
Prince Edward Island	22				9
Nova Scotia	155				62
New Brunswick	127				51
Quebec	1 166				467
Ontario	1 546				618
Manitoba	191				76
Saskatchewan	173				69
Alberta	344				137
British Columbia	462				185
Yukon	4				2
N.W.T.	8				3
TOTAL CANADA	4 303				1 721

* Expressed as SO₂** Expressed as NO₂

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APPENDIX A

TABLE A-1 EMISSIONS OF AIR CONTAMINANTS, NEWFOUNDLAND, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	-	-	-	-	-
Iron ore mining and beneficiation	142 268	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	-	-	-	-	-
Metallurgical coke manufacture	-	-	-	-	-
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	-	-	-	-	-
Primary lead and zinc production	-	-	-	-	-
Copper and nickel refining	-	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	4	-	-	-	1
Asbestos production	7 277	-	-	-	-
Cement manufacture	834	-	-	-	-
Asphalt production	985	-	-	-	-
Lime manufacturing	-	-	-	-	-
Gypsum processing	230	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	80	-	-	-	-
Silica processing	15	-	-	-	-
Stone processing	111	-	-	-	-
Sand and gravel processing	248	-	-	-	-
Mining and rock quarrying	5 581	-	-	-	-

TABLE A-1 EMISSIONS OF AIR CONTAMINANTS, NEWFOUNDLAND, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	338	556	378	-	445
Sulphite pulping	-	3 031	-	-	-
Sulphuric acid production	-	-	-	-	-
Nitric acid production	-	-	-	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	555	-	-	-	-
Phosphate fertilizer manufacture	-	-	-	-	-
Elemental phosphorus production	3 534	689	-	-	-
Nitrate fertilizer manufacture	-	-	-	-	-
Grain handling	-	-	-	-	-
Grain milling	-	-	-	-	-
Clay products manufacture	71	-	-	-	-
Crude oil production	-	-	-	122	-
Petroleum refining***	559	8 337	334	15 740	64 504
Natural gas processing	-	-	-	-	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	-	-	-	-	-
Concrete batching	5	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	-	-	-	-	-
Subtotal	162 695	12 613	712	15 862	64 950

TABLE A-1 EMISSIONS OF AIR CONTAMINANTS, NEWFOUNDLAND, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	498	5 464	1 929	133	456
Residential fuel combustion	143	3 929	1 064	56	291
Industrial fuel combustion	2 220	34 172	8 037	262	343
Commercial fuel combustion	228	3 782	1 004	23	122
Fuelwood combustion	972	-	49	3 402	5 833
Subtotal	4 061	47 347	12 083	3 876	7 045
TRANSPORTATION					
Gasoline-powered motor vehicles	759	316	8 205	14 277	116 208
Railroads	95	501	1 113	263	383
Marine	207	603	647	1 180	2 840
Aircraft	15	24	221	244	736
Off-road use of gasoline	23	17	367	650	12 232
Diesel-powered engines	277	573	7 811	781	4 740
Tire wear	39	-	-	8	-
Subtotal	1 415	2 034	18 364	17 403	137 139

TABLE A-1 EMISSIONS OF AIR CONTAMINANTS, NEWFOUNDLAND, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	-	-	-	-	-
Industrial and commercial incineration	21	13	14	4	15
Sewage sludge incineration	-	-	-	-	-
Wigwam burners	68	1	6	68	808
Subtotal	89	14	20	72	823
MISCELLANEOUS					
Fertilizer application	11	-	-	-	-
Pesticide manufacturing and application	-	-	-	-	-
Gasoline and diesel marketing	-	-	-	3 774	-
Dry cleaning	-	-	-	686	-
Application of surface coatings	-	-	-	2 516	-
Forest fires	63 639	-	14 974	89 843	524 084
Structural fires	42	-	-	42	84
Slash burning	1 256	-	148	295	3 693
Cigarette smoking	105	-	-	-	42
Subtotal	65 053	-	15 122	97 156	527 903
TOTAL	233 313	62 008	46 301	134 369	737 860

* Expressed as SO₂

** Expressed as NO₂

*** Includes emissions from New Brunswick

TABLE A-2 EMISSIONS OF AIR CONTAMINANTS, PRINCE EDWARD ISLAND, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	-	-	-	-	-
Iron ore mining and beneficiation	-	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	-	-	-	-	-
Metallurgical coke manufacture	-	-	-	-	-
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	-	-	-	-	-
Primary lead and zinc production	-	-	-	-	-
Copper and nickel refining	-	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	9	-	-	-	2
Asbestos production	-	-	-	-	-
Cement manufacture	-	-	-	-	-
Asphalt production	1 199	-	-	-	-
Lime manufacturing	-	-	-	-	-
Gypsum processing	-	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	-	-	-	-	-
Stone processing	-	-	-	-	-
Sand and gravel processing	39	-	-	-	-
Mining and rock quarrying	-	-	-	-	-

TABLE A-2 EMISSIONS OF AIR CONTAMINANTS, PRINCE EDWARD ISLAND, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	-	-	-	-	-
Sulphite pulping	-	-	-	-	-
Sulphuric acid production	-	-	-	-	-
Nitric acid production	-	-	-	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	-	-	-	-	-
Phosphate fertilizer manufacture	-	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	-	-	-	-	-
Grain handling	-	-	-	-	-
Grain milling	-	-	-	-	-
Clay products manufacture	-	-	-	-	-
Crude oil production	-	-	-	-	-
Petroleum refining	-	-	-	-	-
Natural gas processing	-	-	-	-	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	-	-	-	-	-
Concrete batching	5	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	-	-	-	-	-
Subtotal	1 252	-	-	-	2

TABLE A-2 EMISSIONS OF AIR CONTAMINANTS, PRINCE EDWARD ISLAND, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	463	5 914	2 219	20	112
Residential fuel combustion	47	1 269	346	18	95
Industrial fuel combustion	546	7 414	1 768	20	103
Commercial fuel combustion	46	780	207	4	26
Fuelwood combustion	384	-	19	1 343	2 302
Subtotal	1 486	15 377	4 559	1 405	2 638
TRANSPORTATION					
Gasoline-powered motor vehicles	250	108	2 733	4 706	38 659
Railroads	73	228	1 008	250	362
Marine	4	15	14	86	240
Aircraft	2	2	18	25	144
Off-road use of gasoline	12	9	195	345	6 495
Diesel-powered engines	46	96	1 309	131	794
Tire wear	13	-	-	3	-
Subtotal	400	456	5 277	5 546	46 694

TABLE A-2 EMISSIONS OF AIR CONTAMINANTS, PRINCE EDWARD ISLAND, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	-	-	-	-	-
Industrial and commercial incineration	6	3	4	1	4
Sewage sludge incineration	-	-	-	-	-
Wigwam burners	19	-	2	19	225
Subtotal	25	3	6	20	229
MISCELLANEOUS					
Fertilizer application	118	-	-	-	-
Pesticide manufacturing and application	22	-	-	-	-
Gasoline and diesel marketing	-	-	-	1 143	-
Dry cleaning	-	-	-	146	-
Application of surface coatings	-	-	-	551	-
Forest fires	38	-	9	54	312
Structural fires	53	-	-	53	106
Slash burning	89	-	11	21	263
Cigarette smoking	22	-	-	-	9
Subtotal	342	-	20	1 968	690
TOTAL	3 505	15 836	9 862	8 939	50 253

* Expressed as SO₂** Expressed as NO₂

TABLE A-3 EMISSIONS OF AIR CONTAMINANTS, NOVA SCOTIA, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	17 785	458	-	-	-
Iron ore mining and beneficiation	-	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	128	-	-	-	-
Metallurgical coke manufacture	669	1 982	2	83	109
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	-	-	-	-	-
Primary lead and zinc production	-	-	-	-	-
Copper and nickel refining	-	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	149	-	-	-	26
Asbestos production	-	-	-	-	-
Cement manufacture	2 509	-	-	-	-
Asphalt production	1 913	-	-	-	-
Lime manufacturing	-	-	-	-	-
Gypsum processing	152	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	13	-	-	-	-
Stone processing	502	-	-	-	-
Sand and gravel processing	420	-	-	-	-
Mining and rock quarrying	3 152	-	-	-	-

TABLE A-3 EMISSIONS OF AIR CONTAMINANTS, NOVA SCOTIA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	3 251	401	273	-	321
Sulphite pulping	337	3 636	-	-	-
Sulphuric acid production	-	-	-	-	-
Nitric acid production	-	-	-	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	-	-	-	-	-
Phosphate fertilizer manufacture	-	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	-	-	-	-	-
Grain handling	372	-	-	-	-
Grain milling	94	-	-	-	-
Clay products manufacture	583	-	-	-	-
Crude oil production	-	-	-	2 369	-
Petroleum refining	1 182	10 147	347	16 058	66 966
Natural gas processing	-	-	-	-	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	-	-	-	-	-
Concrete batching	8	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	1 365	-	-	-	-
Subtotal	34 584	16 624	622	18 510	67 422

TABLE A-3 EMISSIONS OF AIR CONTAMINANTS, NOVA SCOTIA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	20 816	92 622	29 432	514	1 975
Residential fuel combustion	781	10 680	2 395	571	2 648
Industrial fuel combustion	6 223	89 204	20 966	421	1 058
Commercial fuel combustion	651	9 609	2 397	40	208
Fuelwood combustion	1 919	-	96	6 715	11 512
Subtotal	30 390	202 115	55 286	8 261	17 401
TRANSPORTATION					
Gasoline-powered motor vehicles	1 463	619	16 029	27 682	226 780
Railroads	129	462	1 744	426	622
Marine	82	571	335	680	1 782
Aircraft	12	18	185	203	631
Off-road use of gasoline	52	39	831	1 472	27 705
Diesel-powered engines	488	1 009	13 809	1 381	8 382
Tire wear	79	-	-	16	-
Subtotal	2 305	2 718	32 933	31 860	265 902

TABLE A-3 EMISSIONS OF AIR CONTAMINANTS, NOVA SCOTIA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	744	146	176	88	2 058
Industrial and commercial incineration	43	26	28	9	31
Sewage sludge incineration	-	-	-	-	-
Wigwam burners	298	3	27	298	3 519
Subtotal	1 085	175	231	395	5 608
MISCELLANEOUS					
Fertilizer application	73	-	-	-	-
Pesticide manufacturing and application	8	-	-	-	-
Gasoline and diesel marketing	-	-	-	7 518	-
Dry cleaning	-	-	-	1 021	-
Application of surface coatings	-	-	-	3 851	-
Forest fires	5 680	-	1 336	8 020	46 778
Structural fires	191	-	-	191	383
Slash burning	1 852	-	218	436	5 447
Cigarette smoking	155	-	-	-	62
Subtotal	7 959	-	1 554	21 037	52 670
TOTAL	76 323	221 632	90 626	80 063	409 003

* Expressed as SO₂** Expressed as NO₂

TABLE A-4 EMISSIONS OF AIR CONTAMINANTS, NEW BRUNSWICK, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	-	-	-	-	-
Iron ore mining and beneficiation	-	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	231	-	-	-	-
Metallurgical coke manufacture	-	-	-	-	-
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	-	-	-	-	-
Primary lead and zinc production	233	11 979	-	-	-
Copper and nickel refining	-	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	446	-	-	-	118
Asbestos production	-	-	-	-	-
Cement manufacture	356	-	-	-	-
Asphalt production	2 883	-	-	-	-
Lime manufacturing	1 568	-	-	-	-
Gypsum processing	276	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	-	-	-	-	-
Stone processing	1 034	-	-	-	-
Sand and gravel processing	284	-	-	-	-
Mining and rock quarrying	1 539	-	-	-	-

TABLE A-4 EMISSIONS OF AIR CONTAMINANTS, NEW BRUNSWICK, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	8 830	1 522	1 005	-	1 198
Sulphite pulping		9 229	-	-	-
Sulphuric acid production	-	-	-	-	-
Nitric acid production	-	-	-	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	669	-	-	-	-
Phosphate fertilizer manufacture	265	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	-	-	-	-	-
Grain handling	222	-	-	-	-
Grain milling	-	-	-	-	-
Clay products manufacture	195	-	-	-	-
Crude oil production	-	-	-	1 593	-
Petroleum refining***	-	-	-	-	-
Natural gas processing	-	-	-	-	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	28	-	-	-	-
Concrete batching	7	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	-	-	-	-	-
Subtotal	19 066	22 730	1 005	1 593	1 316

TABLE A-4 EMISSIONS OF AIR CONTAMINANTS, NEW BRUNSWICK, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	6 781	53 731	9 133	113	511
Residential fuel combustion	296	7 210	1 821	134	675
Industrial fuel combustion	6 475	87 090	19 995	432	1 058
Commercial fuel combustion	431	6 465	1 631	29	151
Fuelwood combustion	1 791	-	90	6 268	10 745
Subtotal	15 774	154 496	32 670	6 976	13 140
TRANSPORTATION					
Gasoline-powered motor vehicles	1 229	512	13 296	23 335	188 863
Railroads	338	1 347	4 434	1 084	1 577
Marine	45	194	154	552	1 487
Aircraft	14	20	151	240	1 853
Off-road use of gasoline	45	34	733	1 298	24 439
Diesel-powered engines	382	792	10 837	1 084	6 579
Tire wear	65	-	-	13	-
Subtotal	2 118	2 899	29 605	27 606	224 798

TABLE A-4 EMISSIONS OF AIR CONTAMINANTS, NEW BRUNSWICK, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	-	-	-	-	-
Industrial and commercial incineration	33	20	22	7	24
Sewage sludge incineration	-	-	-	-	-
Wigwam burners	517	5	47	517	6 113
Subtotal	550	25	69	524	6 137
MISCELLANEOUS					
Fertilizer application	128	-	-	-	-
Pesticide manufacturing and application	17	-	-	-	-
Gasoline and diesel marketing	-	-	-	6 578	-
Dry cleaning	-	-	-	834	-
Application of surface coatings	-	-	-	3 127	-
Forest fires	1 495	-	352	2 111	12 314
Structural fires	109	-	-	109	217
Slash burning	4 010	-	472	943	11 793
Cigarette smoking	127	-	-	-	51
Subtotal	5 886	-	824	13 702	24 375
TOTAL	43 394	180 150	64 173	50 401	269 766

* Expressed as SO₂

** Expressed as NO₂

*** Included in Newfoundland total.

TABLE A-5 EMISSIONS OF AIR CONTAMINANTS, QUEBEC, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	8 784	-	-	-	175 527
Iron ore mining and beneficiation	110 396	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	1	-	-	-	-
Metallurgical coke manufacture	280	171	1	53	67
Primary aluminum production	14 483	20 579	3 299	539	57 948
Primary copper and nickel production	11 446	601 363	-	-	-
Primary lead and zinc production	188	4 398	-	-	-
Copper and nickel refining	45	-	-	-	-
Ferroalloy manufacture	25 000	510	-	-	11 863
Abrasives manufacture	3 498	5 398	-	-	1 509
Ferrous foundries	3 648	-	-	-	906
Asbestos production	63 014	-	-	-	-
Cement manufacture	56 423	-	-	-	-
Asphalt production	12 281	-	-	-	-
Lime manufacturing	11 164	-	-	-	-
Gypsum processing	3 160	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	465	-	-	-	-
Stone processing	12 296	-	-	-	-
Sand and gravel processing	3 858	-	-	-	-
Mining and rock quarrying	66 982	-	-	-	-

TABLE A-5 EMISSIONS OF AIR CONTAMINANTS, QUEBEC, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	19 064	3 555	2 271	-	2 747
Sulphite pulping	388	28 605	-	-	-
Sulphuric acid production	-	321	-	-	-
Nitric acid production	-	-	310	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	558	-	-	-	-
Phosphate fertilizer manufacture	252	-	-	-	-
Elemental phosphorus production	5 023	1 047	-	-	-
Nitrate fertilizer manufacture	370	-	27	-	-
Grain handling	8 370	-	-	-	-
Grain milling	1 528	-	-	-	-
Clay products manufacture	2 991	-	-	-	-
Crude oil production	-	-	-	1 255	-
Petroleum refining	3 812	23 834	1 180	73 445	115 221
Natural gas processing	-	-	-	-	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	310	-	-	-	-
Concrete batching	106	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	67	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	-	-	-	-	-
Subtotal	450 251	689 781	7 088	75 292	365 788

TABLE A-5 EMISSIONS OF AIR CONTAMINANTS, QUEBEC, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	282	1 908	2 006	176	580
Residential fuel combustion	3 164	61 957	16 962	728	3 577
Industrial fuel combustion	22 193	251 856	62 702	1 936	3 579
Commercial fuel combustion	4 894	74 396	19 772	411	2 021
Fuelwood combustion	16 629	-	831	58 201	99 772
Subtotal	47 162	390 117	102 273	61 452	109 529
TRANSPORTATION					
Gasoline-powered motor vehicles	10 255	4 190	110 913	198 911	1 591 150
Railroads	1 284	6 404	15 825	3 816	5 552
Marine	200	1 899	919	3 142	8 663
Aircraft	90	127	1 179	1 434	6 407
Off-road use of gasoline	100	75	1 605	2 844	53 521
Diesel-powered engines	2 713	5 633	75 964	7 596	46 032
Tire wear	590	-	-	118	-
Subtotal	15 232	18 328	206 405	217 861	1 711 325

TABLE A-5 EMISSIONS OF AIR CONTAMINANTS, QUEBEC, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	2 681	751	860	430	10 265
Industrial and commercial incineration	332	199	217	66	239
Sewage sludge incineration	-	-	-	-	-
Wigwam burners	3 854	35	350	3 854	45 543
Subtotal	6 867	985	1 427	4 350	56 047
MISCELLANEOUS					
Fertilizer application	866	-	-	-	-
Pesticide manufacturing and application	70	-	-	-	-
Gasoline and diesel marketing	-	-	-	53 725	-
Dry cleaning	-	-	-	7 660	-
Application of surface coatings	-	-	-	37 414	-
Forest fires	18 446	-	4 340	26 042	151 908
Structural fires	1 497	-	-	1 497	2 993
Slash burning	15 576	-	1 832	3 665	45 812
Cigarette smoking	1 166	-	-	-	467
Subtotal	37 621	-	6 172	130 003	201 180
TOTAL	557 133	1 099 211	323 365	488 958	2 443 869

* Expressed as SO₂** Expressed as NO₂

TABLE A-6 EMISSIONS OF AIR CONTAMINANTS, ONTARIO, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	19 320	1 783	-	-	30 102
Iron ore mining and beneficiation	73 301	175 829	-	-	41 030
Pyrrhotite roasting	3 185	58 590	-	-	-
Coal industry	451	-	-	-	-
Metallurgical coke manufacture	5 700	4 604	20	1 462	1 335
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	12 926	1 367 768	-	-	-
Primary lead and zinc production	97	2 052	-	-	-
Copper and nickel refining	2 928	1 950	-	-	-
Ferroalloy manufacture	55	-	-	-	-
Abrasives manufacture	4 507	3 741	-	-	4 536
Ferrous foundries	4 290	-	-	-	4 598
Asbestos production	2 198	-	-	-	-
Cement manufacture	1 598	-	-	-	-
Asphalt production	6 487	-	-	-	-
Lime manufacturing	9 316	-	-	-	-
Gypsum processing	4 390	-	-	-	-
Nepheline syenite processing	415	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	619	-	-	-	-
Stone processing	8 654	-	-	-	-
Sand and gravel processing	3 440	-	-	-	-
Mining and rock quarrying	6 468	-	-	-	-

TABLE A-6 EMISSIONS OF AIR CONTAMINANTS, ONTARIO, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	12 523	3 669	2 495	-	2 935
Sulphite pulping	231	12 440	-	-	-
Sulphuric acid production	-	1 712	-	-	-
Nitric acid production	-	-	1 230	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	916	-	-	-	-
Phosphate fertilizer manufacture	729	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	1 461	-	97	-	-
Grain handling	9 962	-	-	-	-
Grain milling	2 093	-	-	-	-
Clay products manufacture	7 654	-	-	-	-
Crude oil production	-	-	-	30	-
Petroleum refining	3 073	32 660	1 190	19 221	104 500
Natural gas processing	-	186	-	49	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	833	-	-	-	-
Concrete batching	176	-	-	-	-
Magnesium production	251	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	10	1 358	-	61	87 812
Salt production	6 786	-	-	-	-
Subtotal	217 043	1 668 342	5 032	20 823	276 848

TABLE A-6 EMISSIONS OF AIR CONTAMINANTS, ONTARIO, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	7 518	387 220	89 949	1 223	4 574
Residential fuel combustion	2 418	27 742	17 029	1 087	4 296
Industrial fuel combustion	18 982	194 817	77 081	1 952	5 418
Commercial fuel combustion	2 053	19 493	15 160	704	2 166
Fuelwood combustion	8 314	-	416	29 100	49 886
Subtotal	39 285	629 272	199 635	34 066	66 340
TRANSPORTATION					
Gasoline-powered motor vehicles	15 488	6 497	170 494	294 509	2 414 302
Railroads	2 282	5 687	32 457	8 053	11 715
Marine	172	2 313	1 079	9 998	28 978
Aircraft	121	171	1 539	2 048	11 850
Off-road use of gasoline	616	464	9 943	17 618	331 611
Diesel-powered engines	3 158	6 563	87 749	8 775	53 114
Tire wear	894	-	-	179	-
Subtotal	22 731	21 695	303 261	341 180	2 851 570

TABLE A-6 EMISSIONS OF AIR CONTAMINANTS, ONTARIO, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	2 664	514	589	295	7 038
Industrial and commercial incineration	517	311	338	104	373
Sewage sludge incineration	146	677	203	51	Neg.
Wigwam burners	1 865	17	170	1 865	22 039
Subtotal	5 192	1 519	1 300	2 315	29 450
MISCELLANEOUS					
Fertilizer application	2 138	-	-	-	-
Pesticide manufacturing and application	424	-	-	-	-
Gasoline and diesel marketing	-	-	-	77 818	-
Dry cleaning	-	-	-	10 172	-
Application of surface coatings	-	-	-	59 860	-
Forest fires	176 251	-	41 471	248 824	1 451 475
Structural fires	2 089	-	-	2 089	4 178
Slash burning	9 580	-	1 127	2 254	28 178
Cigarette smoking	1 546	-	-	-	618
Subtotal	192 028	-	42 598	401 017	1 484 449
TOTAL	476 279	2 320 828	551 826	799 401	4 708 657

* Expressed as SO₂** Expressed as NO₂

Neg.- negligible

TABLE A-7 EMISSIONS OF AIR CONTAMINANTS, MANITOBA, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	383	-	-	-	1 176
Iron ore mining and beneficiation	-	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	1 403	-	-	-	-
Metallurgical coke manufacture	-	-	-	-	-
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	12 736	571 526	-	-	-
Primary lead and zinc production	-	-	-	-	-
Copper and nickel refining	24	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	659	-	-	-	78
Asbestos production	-	-	-	-	-
Cement manufacture	2 008	-	-	-	-
Asphalt production	2 573	-	-	-	-
Lime manufacturing	1 624	-	-	-	-
Gypsum processing	546	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	366	-	-	-	-
Stone processing	458	-	-	-	-
Sand and gravel processing	806	-	-	-	-
Mining and rock quarrying	599	-	-	-	-

TABLE A-7 EMISSIONS OF AIR CONTAMINANTS, MANITOBA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	850	357	243	-	286
Sulphite pulping	-	606	-	-	-
Sulphuric acid production	-	761	-	-	-
Nitric acid production	-	-	556	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	-	-	-	-	-
Phosphate fertilizer manufacture	202	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	362	-	25	-	-
Grain handling	4 774	-	-	-	-
Grain milling	676	-	-	-	-
Clay products manufacture	42	-	-	-	-
Crude oil production	-	-	-	194	-
Petroleum refining	241	2 203	71	4 953	13 666
Natural gas processing	-	-	-	-	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	-	-	-	-	-
Concrete batching	11	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	59	-	-	-	-
Subtotal	31 402	575 453	895	5 147	15 206

TABLE A-7 EMISSIONS OF AIR CONTAMINANTS, MANITOBA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	4 534	7 558	7 802	227	755
Residential fuel combustion	193	1 306	1 442	117	374
Industrial fuel combustion	3 114	10 810	5 740	223	513
Commercial fuel combustion	166	1 178	1 442	78	221
Fuelwood combustion	1 535	-	77	5 372	9 210
Subtotal	9 542	20 852	16 503	6 017	11 073
TRANSPORTATION					
Gasoline-powered motor vehicles	2 372	995	25 624	44 730	362 416
Railroads	2 228	2 244	10 580	2 620	3 826
Marine	2	11	12	1 200	3 528
Aircraft	28	36	337	428	1 840
Off-road use of gasoline	181	137	2 926	5 185	97 585
Diesel-powered engines	615	1 274	17 413	1 741	10 569
Tire wear	126	-	-	25	-
Subtotal	5 552	4 697	56 892	55 929	479 764

TABLE A-7 EMISSIONS OF AIR CONTAMINANTS, MANITOBA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	1 687	120	142	71	1 669
Industrial and commercial incineration	56	34	37	11	41
Sewage sludge incineration	-	-	-	-	-
Wigwam burners	153	1	14	153	1 809
Subtotal	1 896	155	193	235	3 519
MISCELLANEOUS					
Fertilizer application	831	-	-	-	-
Pesticide manufacturing and application	572	-	-	-	-
Gasoline and diesel marketing	-	-	-	8 715	-
Dry cleaning	-	-	-	1 254	-
Application of surface coatings	-	-	-	4 864	-
Forest fires	41 494	-	9 763	58 580	341 712
Structural fires	650	-	-	650	1 301
Slash burning	935	-	110	220	2 751
Cigarette smoking	191	-	-	-	76
Subtotal	44 673	-	9 873	74 283	345 840
TOTAL	93 065	601 157	84 356	141 612	855 402

* Expressed as SO₂** Expressed as NO₂

*** Emissions are included under primary copper and nickel production to maintain confidentiality.

TABLE A-8 EMISSIONS OF AIR CONTAMINANTS, SASKATCHEWAN, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	1 693	-	-	-	3 388
Iron ore mining and beneficiation	-	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	1 639	-	-	-	-
Metallurgical coke manufacture	138	382	1	92	79
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	-	-	-	-	-
Primary lead and zinc production	-	-	-	-	-
Copper and nickel refining	-	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	28	-	-	-	5
Asbestos production	-	-	-	-	-
Cement manufacture	1 133	-	-	-	-
Asphalt production	3 590	-	-	-	-
Lime manufacturing	-	-	-	-	-
Gypsum processing	330	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	64	-	-	-	-
Stone processing	-	-	-	-	-
Sand and gravel processing	431	-	-	-	-
Mining and rock quarrying	4 695	-	-	-	-

TABLE A-8 EMISSIONS OF AIR CONTAMINANTS, SASKATCHEWAN, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	3 553	550	374	-	440
Sulphite pulping	-	-	-	-	-
Sulphuric acid production	-	276	-	-	-
Nitric acid production	-	-	-	-	-
Potash processing	20 207	-	-	-	-
Phosphate rock processing	-	-	-	-	-
Phosphate fertilizer manufacture	-	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	-	-	-	-	-
Grain handling	13 155	-	-	-	-
Grain milling	537	-	-	-	-
Clay products manufacture	445	-	-	-	-
Crude oil production	-	-	-	2 693	-
Petroleum refining	551	1 712	94	14 408	-
Natural gas processing	-	255	-	40	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	-	-	-	-	-
Concrete batching	31	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	611	-	-	-	-
Subtotal	52 831	3 175	469	17 233	3 912

TABLE A-8 EMISSIONS OF AIR CONTAMINANTS, SASKATCHEWAN, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	37 593	26 675	29 468	545	1 889
Residential fuel combustion	268	1 820	1 832	166	574
Industrial fuel combustion	1 019	4 182	6 336	161	458
Commercial fuel combustion	59	199	643	39	107
Fuelwood combustion	2 047	-	102	7 163	12 280
Subtotal	40 986	32 876	38 381	8 074	15 308
TRANSPORTATION					
Gasoline-powered motor vehicles	3 202	1 378	34 708	59 266	488 076
Railroads	395	1 013	5 572	1 381	2 008
Marine	-	7	7	1 160	3 413
Aircraft	14	18	158	244	1 549
Off-road use of gasoline	590	445	9 518	16 866	317 447
Diesel-powered engines	1 215	2 516	34 408	3 441	20 886
Tire wear	152	-	-	30	-
Subtotal	5 568	5 377	84 371	82 388	833 379

TABLE A-8 EMISSIONS OF AIR CONTAMINANTS, SASKATCHEWAN, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	124	21	18	9	251
Industrial and commercial incineration	42	25	27	8	30
Sewage sludge incineration	4	1	5	1	Neg.
Wigwam burners	310	3	28	310	3 659
Subtotal	480	50	78	328	3 940
MISCELLANEOUS					
Fertilizer application	640	-	-	-	-
Pesticide manufacturing and application	1 091	-	-	-	-
Gasoline and diesel marketing	-	-	-	9 068	-
Dry cleaning	-	-	-	1 137	-
Application of surface coatings	-	-	-	4 369	-
Forest fires	29 473	-	6 935	41 608	242 713
Structural fires	260	-	-	260	521
Slash burning	1 539	-	181	361	4 515
Cigarette smoking	173	-	-	-	69
Subtotal	33 176	-	7 116	56 803	247 818
TOTAL	133 041	41 478	130 415	164 826	1 104 357

* Expressed as SO₂

** Expressed as NO₂

Neg.- negligible

TABLE A-9 EMISSIONS OF AIR CONTAMINANTS, ALBERTA, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	307	-	-	-	1 682
Iron ore mining and beneficiation	-	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	3 042	-	-	-	-
Metallurgical coke manufacture	-	-	-	-	-
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	-	-	-	-	-
Primary lead and zinc production	-	-	-	-	-
Copper and nickel refining	-	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	623	-	-	-	258
Asbestos production	-	-	-	-	-
Cement manufacture	2 814	-	-	-	-
Asphalt production	1 250	-	-	-	-
Lime manufacturing	1 810	-	-	-	-
Gypsum processing	988	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	73	-	-	-	-
Stone processing	140	-	-	-	-
Sand and gravel processing	1 226	-	-	-	-
Mining and rock quarrying	939	-	-	-	-

TABLE A-9 EMISSIONS OF AIR CONTAMINANTS, ALBERTA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	3 043	10 001	728	-	859
Sulphite pulping	-	-	-	-	-
Sulphuric acid production	-	4 811	-	-	-
Nitric acid production	-	-	5 392	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	1 222	-	-	-	-
Phosphate fertilizer manufacture	2 020	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	1 458	-	92	-	-
Grain handling	8 140	-	-	-	-
Grain milling	864	-	-	-	-
Clay products manufacture	996	-	-	-	-
Crude oil production	-	-	-	21 105	-
Petroleum refining	2 078	3 177	777	13 427	23 430
Natural gas processing	-	343 100	-	6 004	-
Tar sands operations	14 370	93 000	5 734	-	319
Glass manufacturing	36	-	-	-	-
Concrete batching	61	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	650	-	-	-	-
Subtotal	48 150	454 089	12 723	40 536	26 548

TABLE A-9 EMISSIONS OF AIR CONTAMINANTS, ALBERTA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	108 244	32 398	29 654	953	3 495
Residential fuel combustion	1 464	1 836	3 169	1 346	5 518
Industrial fuel combustion	2 350	14 378	144 732	1 701	1 113
Commercial fuel combustion	381	166	4 544	301	759
Fuelwood combustion	1 100	-	55	3 850	6 600
Subtotal	113 539	48 778	182 154	8 151	17 485
TRANSPORTATION					
Gasoline-powered motor vehicles	5 144	2 211	56 535	96 151	796 529
Railroads	471	1 095	6 791	1 689	2 456
Marine	-	8	9	1 470	4 323
Aircraft	55	73	653	901	4 811
Off-road use of gasoline	596	450	9 628	17 062	321 132
Diesel-powered engines	1 917	3 973	54 141	5 414	32 851
Tire wear	266	-	-	53	-
Subtotal	8 449	7 810	127 757	122 740	1 162 102

TABLE A-9 EMISSIONS OF AIR CONTAMINANTS, ALBERTA, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	-	-	-	-	-
Industrial and commercial incineration	94	57	62	19	68
Sewage sludge incineration	-	-	-	-	-
Wigwam burners	808	7	74	808	9 548
Subtotal	902	64	136	827	9 616
MISCELLANEOUS					
Fertilizer application	1 298	-	-	-	-
Pesticide manufacturing and application	745	-	-	-	-
Gasoline and diesel marketing	-	-	-	20 385	-
Dry cleaning	-	-	-	2 281	-
Application of surface coatings	-	-	-	8 623	-
Forest fires	7 276	-	1 712	10 271	59 915
Structural fires	691	-	-	691	1 382
Slash burning	3 015	-	355	709	8 866
Cigarette smoking	344	-	-	-	137
Subtotal	13 369	-	2 067	42 960	70 300
TOTAL	184 409	510 741	324 837	215 214	1 286 051

* Expressed as SO₂** Expressed as NO₂

TABLE A-10 EMISSIONS OF AIR CONTAMINANTS, BRITISH COLUMBIA, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	264	-	-	-	759
Iron ore mining and beneficiation	3 749	-	-	-	-
Pyrrhotite roasting	250	5 390	-	-	-
Coal industry	55 251	-	-	-	-
Metallurgical coke manufacture	526	299	1	41	53
Primary aluminum production	2 360	7 285	1 806	292	31 336
Primary copper and nickel production	-	-	-	-	-
Primary lead and zinc production	589	16 536	-	-	-
Copper and nickel refining	-	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	490	-	-	-	170
Asbestos production	5 759	-	-	-	-
Cement manufacture	791	-	-	-	-
Asphalt production	4 115	-	-	-	-
Lime manufacturing	678	-	-	-	-
Gypsum processing	2 566	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	13	-	-	-	-
Stone processing	824	-	-	-	-
Sand and gravel processing	1 705	-	-	-	-
Mining and rock quarrying	29 688	-	-	-	-

TABLE A-10 EMISSIONS OF AIR CONTAMINANTS, BRITISH COLUMBIA, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	46 169	10 919	7 425	-	8 736
Sulphite pulping	-	8 924	-	-	-
Sulphuric acid production	-	185	-	-	-
Nitric acid production	-	-	-	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	226	-	-	-	-
Phosphate fertilizer manufacture	599	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	-	-	-	-	-
Grain handling	4 247	-	-	-	-
Grain milling	-	-	-	-	-
Clay products manufacture	514	-	-	-	-
Crude oil production	-	-	-	777	-
Petroleum refining	1 233	9 901	435	16 288	62 871
Natural gas processing	-	229 190	-	3	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	71	-	-	-	-
Concrete batching	45	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	-	-	-	-	-
Subtotal	162 722	288 629	9 667	17 401	103 925

TABLE A-10 EMISSIONS OF AIR CONTAMINANTS, BRITISH COLUMBIA, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	197	387	2 257	202	662
Residential fuel combustion	510	4 814	3 621	259	931
Industrial fuel combustion	4 963	57 978	23 406	820	1 320
Commercial fuel combustion	488	4 700	3 533	162	497
Fuelwood combustion	256	-	13	895	1 535
Subtotal	6 414	67 879	32 830	2 338	4 945
TRANSPORTATION					
Gasoline-powered motor vehicles	5 977	2 582	66 617	111 918	936 495
Railroads	1 044	2 997	14 567	3 607	5 246
Marine	335	1 045	1 097	3 991	10 764
Aircraft	67	94	811	1 216	6 951
Off-road use of gasoline	152	115	2 461	4 361	82 078
Diesel-powered engines	2 020	4 181	56 737	5 674	34 407
Tire wear	322	-	-	64	-
Subtotal	9 917	11 014	142 290	130 831	1 075 941

TABLE A-10 EMISSIONS OF AIR CONTAMINANTS, BRITISH COLUMBIA, 1976
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	65	15	4	3	129
Industrial and commercial incineration	137	82	90	28	99
Sewage sludge incineration	17	3	4	1	Neg.
Wigwam burners	16 860	153	1 533	16 860	199 256
Subtotal	17 079	253	1 631	16 892	199 484
MISCELLANEOUS					
Fertilizer application	152	-	-	-	-
Pesticide manufacturing and application	27	-	-	-	-
Gasoline and diesel marketing	-	-	-	22 329	-
Dry cleaning	-	-	-	3 035	-
Application of surface coatings	-	-	-	15 620	-
Forest fires	18 447	-	4 340	26 043	151 914
Structural fires	660	-	-	660	1 320
Slash burning	37 263	-	4 384	8 768	109 598
Cigarette smoking	462	-	-	-	185
Subtotal	57 011	-	8 724	76 455	263 017
TOTAL	253 143	367 775	195 142	243 917	1 647 312

* Expressed as SO₂** Expressed as NO₂

Neg.- negligible

TABLE A-11 EMISSIONS OF AIR CONTAMINANTS, YUKON AND NORTHWEST TERRITORIES, 1976

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron and steel production	-	-	-	-	-
Iron ore mining and beneficiation	-	-	-	-	-
Pyrrhotite roasting	-	-	-	-	-
Coal industry	-	-	-	-	-
Metallurgical coke manufacture	-	-	-	-	-
Primary aluminum production	-	-	-	-	-
Primary copper and nickel production	-	-	-	-	-
Primary lead and zinc production	-	-	-	-	-
Copper and nickel refining	-	-	-	-	-
Ferroalloy manufacture	-	-	-	-	-
Abrasives manufacture	-	-	-	-	-
Ferrous foundries	-	-	-	-	-
Asbestos production	8 455	-	-	-	-
Cement manufacture	-	-	-	-	-
Asphalt production	28	-	-	-	-
Lime manufacturing	-	-	-	-	-
Gypsum processing	-	-	-	-	-
Nepheline syenite processing	-	-	-	-	-
Fluorspar processing	-	-	-	-	-
Silica processing	-	-	-	-	-
Stone processing	-	-	-	-	-
Sand and gravel processing	-	-	-	-	-
Mining and rock quarrying	3 898	-	-	-	-

TABLE A-11 EMISSIONS OF AIR CONTAMINANTS, YUKON AND NORTHWEST TERRITORIES, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Sulphate (kraft) pulping	-	-	-	-	-
Sulphite pulping	-	-	-	-	-
Sulphuric acid production	-	-	-	-	-
Nitric acid production	-	-	-	-	-
Potash processing	-	-	-	-	-
Phosphate rock processing	-	-	-	-	-
Phosphate fertilizer manufacture	-	-	-	-	-
Elemental phosphorus production	-	-	-	-	-
Nitrate fertilizer manufacture	-	-	-	-	-
Grain handling	-	-	-	-	-
Grain milling	-	-	-	-	-
Clay products manufacture	-	-	-	-	-
Crude oil production	-	-	-	43	-
Petroleum refining***	-	-	-	-	-
Natural gas processing	1	-	-	2	-
Tar sands operations	-	-	-	-	-
Glass manufacturing	-	-	-	-	-
Concrete batching	-	-	-	-	-
Magnesium production	-	-	-	-	-
Phosphoric acid production	-	-	-	-	-
Carbon black	-	-	-	-	-
Salt production	-	-	-	-	-
Subtotal	12 382	-	-	45	-

TABLE A-11 EMISSIONS OF AIR CONTAMINANTS, YUKON AND NORTHWEST TERRITORIES, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	234	446	2 605	243	790
Residential fuel combustion	9	110	60	4	17
Industrial fuel combustion	95	1 410	517	15	64
Commercial fuel combustion	20	387	201	8	43
Fuelwood combustion	281	-	14	985	1 688
Subtotal	639	2 353	3 397	1 255	2 602
TRANSPORTATION					
Gasoline-powered motor vehicles	142	61	1 537	2 637	21 628
Railroads	11	29	143	33	48
Marine	1	3	4	3	4
Aircraft	20	17	130	187	1 039
Off-road use of gasoline	7	5	110	195	3 664
Diesel-powered engines	313	648	8 857	885	5 377
Tire wear	6	-	-	2	-
Subtotal	500	763	10 781	3 942	31 760

TABLE A-11 EMISSIONS OF AIR CONTAMINANTS, YUKON AND NORTHWEST TERRITORIES, 1976 (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
SOLID WASTE INCINERATION					
Municipal incineration	-	-	-	-	-
Industrial and commercial incineration	3	2	2	1	2
Sewage sludge incineration	-	-	-	-	-
Wigwam burners	7	-	1	7	86
Subtotal	10	2	3	8	88
MISCELLANEOUS					
Fertilizer application	-	-	-	-	-
Pesticide manufacturing and application	-	-	-	-	-
Gasoline and diesel marketing	-	-	-	567	-
Dry cleaning	-	-	-	80	-
Application of surface coatings	-	-	-	296	-
Forest fires	225 007	-	52 942	317 656	1 852 997
Structural fires	27	-	-	27	53
Slash burning	67	-	8	16	197
Cigarette smoking	12	-	-	-	5
Subtotal	225 113	-	52 950	318 642	1 853 252
TOTAL	238 644	3 118	67 131	323 892	1 887 702

* Expressed as SO₂** Expressed as NO₂

*** Included with British Columbia total

APPENDIX B

FUGITIVE DUSTS FROM UNPAVED ROADS

Fugitive dusts from unpaved roads contribute significantly to the particulate matter burden in the atmosphere according to various EPA studies (1, 2). As a result, this emission source has been examined to determine its contribution to total emissions of particulate matter in Canada.

Based on very limited data and numerous assumptions, it is estimated that 91.7 percent of the total particulate emissions in Canada (Table B-1) originate from this source. These results are regarded as preliminary and additional data are required before incorporation into the main body of this report and inclusion in the provincial summary tables.

TABLE B-1 NATIONWIDE EMISSIONS OF PARTICULATE MATTER, 1976

Category	Particulate Emissions (t x 10 ³)	% of total
Industrial Processes	1 192	4.3
Fuel Combustion/Stationary Sources	309	1.1
Transportation	74	0.3
Solid Waste Incineration	34	0.1
Miscellaneous	682	2.5
Unpaved Roads	25 344	91.7
TOTAL	27 635	100.0

The fugitive dusts from unpaved roads are generated through a combination of wind action and activities of man, principally vehicular traffic. This type of particulate matter differs significantly from that produced by the physical and chemical processes or operations discussed in the main body of the report. The environmental effects of the two types of particulate matter are generally different and as such they should not be viewed in the same context.

Emission Sources

Three general types of unpaved road surfaces have been considered: treated and untreated gravel roads, and earth roads. On all three types, the forces created by the

wheels of a moving vehicle pulverize the surface materials; particles are lifted and dropped from the rolling wheels under the action of turbulent air currents. Certain soil characteristics and meteorological conditions enhance the formation of dust plumes.

Controls

A dust control efficiency of 50 percent was assumed for gravel roads treated with used oil or other chemicals such as calcium chloride (CaCl_2) (1,3). Little or no control is used on earth roads. Restricted vehicle speed is another potentially effective method of control (1); however it was assumed that no such control is presently in effect.

Emissions

Dust emissions from unpaved roads were estimated using an empirical equation developed from actual test measurements (4). For each type of unpaved road surface, emissions were found to depend on the following factors: number of vehicle miles, average vehicle speed, number of wheels per vehicle (vehicle mix) surface texture and surface moisture. Data on the number of vehicle-miles per road type were found from a study done for one province (5). This information was used to estimate vehicle-miles per road type for all provinces based on total road mileage. Average vehicle speed for gravel and earth roads was estimated based on an EPA document (9). Data on vehicle mix, surface texture and surface moisture were obtained from other government departments (6, 7, 8).

The emission factors and emissions are presented in Table B-2 and Table B-3 respectively.

TABLE B-2 PROVINCIAL EMISSION FACTORS, UNPAVED ROADS

Province	Particulate Emission Factors (kg/vehicle-mile)	
	Gravel Roads	Earth Roads
Newfoundland	0.98	2.05
Prince Edward Island	1.13	3.15
Nova Scotia	1.17	2.84
New Brunswick	1.13	2.75
Quebec	1.06	1.47
Ontario	1.10	1.91
Manitoba	1.21	2.09
Saskatchewan	1.32	3.65
Alberta	1.24	2.59
British Columbia	1.10	1.91
Yukon	0.84	2.04
Northwest Territories	0.69	1.69
CANADA	1.06	2.21

TABLE B-3 TOTAL EMISSIONS, UNPAVED ROADS, 1976

Province	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Newfoundland	415 171				
Prince Edward Island	73 001				
Nova Scotia	1 037 530				
New Brunswick	663 992				
Quebec	3 994 473				
Ontario	8 998 107				
Manitoba	1 623 259				
Saskatchewan	1 804 629				
Alberta	4 072 842				
British Columbia	2 476 115				
Yukon, NWT	184 617				
TOTAL CANADA	25 343 736				

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